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for March, 1936

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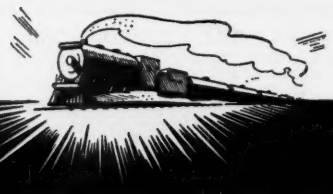
From A to Z



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ÉTIENNE-FRANÇOIS GEOFFROY (1672–1731)

Geoffroy, the elder, studied medicine at Montpellier, visited London in 1698 where he was made a member of the Royal Society, and later traveled in Holland and in Italy where he studied natural history. In 1712 he became Professor of Chemistry at the Jardin du Roi and Physician to the King of France. His principal contribution to chemistry lay in his work on affinities, published in a "Table of the different relations observed in chemistry between different substances" and based upon the "law," really a definition of affinity that "whenever two substances which have a certain tendency to combine with one another are united together, if a third is added which has more affinity for one of the two, it combines with that one letting go of the other."

(Contributed by Tenney L. Davis)

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EDITOR'S OUTLOOK

DEVELOPMENT OF THE CRITICAL SENSE. Teachers of prospective chemists and directors of chemists newly entered upon professional careers often find occasion to regret that their charges do not give evidence of high development of the critical sense. The advanced student and the young chemist are sometimes thorough library searchers and often competent laboratory technicians, but they are far too often inclined to ascribe equal significance and reliability to any and all statements that they see in print.

We would not deny that a sound critical faculty requires time and experience for full development and ripening, but we do contend that many teachers and most textbooks do less than they should to facilitate the process. When a student is accustomed to receive, and memorize for reproduction, unsupported statements, data unaccompanied by critical commentary, and generalizations divorced from the experimental observations upon which they are presumably based, can there be any wonder that he does not develop the habit of exercising a discrimination for which he has never sensed any need?

As regards teachers it is, of course, difficult to support our argument with objective evidence. Textbooks, however, tell their own story and are open to general inspection.

In our opinion it is a part of the function of any textbook beyond the most elementary level to aid in the introduction of the professional literature to the student, and to aid the student in the development of good professional reading habits. To this end we advocate that all advanced textbooks emulate good monographs by furnishing adequate supporting references for the statements made, and by presenting in some detail the data upon which generalizations are based.

One might raise the objection that this practice would result in the physical expansion of textbooks and a consequent increase in their cost of production. Let us examine this objection on the basis of a 35-chapter, 650-page text. If fifty pages of supporting references were added to such a text, the probable necessary increase in retail selling price would be twenty-five to fifty cents—at most, the cost of a movie ticket and a midnight snack. Surely that would not be an immoderate addition to the student's educational investment if he received in return any appreciable educational value at all.

Just how much value he might receive would depend to a considerable extent upon his teacher, and upon the actual use he was required to make of the reference material supplied. If he never did any more about references than to note their presence, however, it would probably be borne in upon him that there is some difference between certified and uncertified checks and that, in general, the former are better risks than the latter. That consciousness alone ought to be worth fifty cents to him.

Some authors would find the labors of authorship greatly increased. On the basis of a fair general reading knowledge and a good memory, aided by a few convenient secondary reference sources, it is possible to toss off very rapidly rather respectable-appearing chapters which it would take hours of library labor to support in detail. Authors who work in this manner, however, would often be surprised to find out how much they know that isn't so. The really conscientious author scrupulously verifies his material, whether he ever produces his verification for public inspection or not. His labors would not be greatly increased by the incorporation of his source references and his critical evalutions into his manuscript.

At the elementary (*i. e.*, the general chemistry) level it is perhaps questionable that numerous textbook references to original literature have any great value. Nevertheless, the same general spirit of presentation should be employed, through liberal use of the historical approach and through introduction to all generalizations by way of the experimental facts on which they are based.

The cover picture is a reproduction of another of Thomas Wijck's "Alchymist" paintings. The original hangs in the Hague art gallery. For loan of the photograph we are indebted to Dr. R. E. Oesper.

KO HUNG *on the* GOLD MEDICINE*

TENNEY L. DAVIS AND LU-CH'IANG WU

Massachusetts Institute of Technology, Cambridge, Massachusetts, and Sun Yatsen University, Canton, China

A PAPER on Ko Hung in the September, 1934, number of THIS JOURNAL (11, 517–20) constituted a survey of all of the material concerning him which was readily accessible in European languages, together with certain new material—the biography of Ko Hung translated by Lu-Ch'iang Wu from the Chinese of the *Lieh Hsien Ch'üan chuan* (Complete Biographies of the Immortals). Further material has been received recently from China; a complete translation† by Dr. Wu of Ko Hung's chapter on the Gold Medicine (the fourth of the Inner Chapters of *Pao-p'u-tzu*) and photographs of the hill, now known as Ko's Hill, at the West Lake, Hangchow, where Ko Hung is supposed to have lived and written and experimented, together with photographs of the buildings on the hill and a print of the stone tablet on which a portrait of the alchemist is carved. The translation in its entirety will be published elsewhere.‡ In the present paper we wish only to survey the chapter on the Gold Medicine and to report upon its contents. A translation of Ko Hung's chapter on the Yellow and White (the sixteenth of the Inner Chapters of *Pao-p'u-tzu*) has been completed and will provide a subject for a later report. The two chapters probably constitute the most important of Ko Hung's writings on alchemy.

The chapter on the Gold Medicine deals primarily with the preparation and effects of various medicines of immortality, while that on the Yellow and White treats especially of transmutation. Among the elixirs mentioned in the present chapter there are, however, certain ones which respectively convert mercury, copper, and lead to gold, another which converts lead to silver and to gold, and one in particular which converts mercury into silver of such sort that this silver converts further lead into silver, in which respect it resembles the *ferment* of the Arabian alchemists.

PRINT OF THE STONE TABLET. THE WORDS AT THE TOP MAY BE TRANSLATED—PORTRAIT OF KO HUNG, THE MARQUIS OF KUAN NEI OF THE CHIN DYNASTY

After cooking for thirty days, a mixture of *Chin I* (Gold Fluid) and quicksilver is placed in a yellow earthen jar, which is then sealed with Six-One Mud and strongly heated for sixty hours. Thereupon the medicine is obtained. The swallowing of a pea-size quantity of the medicine is enough to make a *hsien* out of any person. Silver is obtained by sprinkling a knifebladeful of this medicine onto a catty** of quicksilver. When a catty of this medicine is placed over a fire and fanned, red gold is obtained which will flow and is called *Tan Chin* (Medicine Gold). Swords besmeared with this medicine have the power of checking enemies at a distance of ten thousand miles. By eating and drinking out of vessels made of this medicine, one will attain immortality. The medicine may be exposed to the sun and moon to obtain a liquid which is also an elixir. When a mixture of the Gold Fluid and Yellow Earth is strongly heated in a jar made of Six-One Mud, it is entirely changed into serviceable yellow gold.

When the latter is again heated, *Tan* is obtained, a pea-size dose of which is potent enough to make a *Ti Hsien* (Earthly Spirit, an Immortal of the Earth) in celebrated mountains and great rivers. Silver is obtained when a knifebladeful of this medicine is sprinkled onto quicksilver. When an ounce of this silver is mixed with a catty of lead the entire mass is changed into silver.

---

* Presented before the Division of History of Chemistry at the eighty-ninth meeting of the American Chemical Society, New York, April 22, 1935.

† For financial aid in defraying the expenses of the preparation of these translations, we wish to make grateful acknowledgment of a grant from the Permanent Science Fund of the American Academy of Arts and Sciences.

‡ Since this paper was delivered the translation has appeared, *Proc. Am. Acad. Arts and Sciences*, **70**, 221–84 (Dec., 1935).

** A weight of the East Indies, China, etc., commonly equal to about $1^1/_3$ lb.

Ko Hung speaks of the general ignorance of the art and of the pretentiousness of those who are ignorant. He points out that vegetable substances are not suitable materials for the preparation of the medicine, for these, unlike *tan sha* (cinnabar), turn to ashes when they are burned. He describes the Nine Furnace-Pot Medicines, and thirty-four others of which he ascribes twenty-one to various alchemists whom he names. He mentions the necessity for offerings, ceremonials, and various precautions.

In compounding the medicine the chief thing to be guarded against is the ridicule of the disbeliever. For such derision is sure to prevent the success of the compounding. According to the words of *Chêng Chün*, he who attempts the compounding of this medicine must make offerings to the gods, from among whom *T'ai I* (Supreme Monad), *Yüan Chün*, *Lao Chün*, and *Hsüan Nü* will come to watch over the operations. If the compounder should let stupid people of the world know of his doings by not working in a secluded place, the gods would withhold their blessings, whereupon the evil *Ch'i* (ethereal essences) would enter to spoil the medicine. In order to be successful the compounder must work in a famous mountain retreat in isolation from the mass. He should practice dieting, refraining from the five stimulant foods, namely, leeks, garlic, scallions, smartweed, and mustard, and from raw fish, for a hundred days before beginning the work and continuing until the medicine is done.

Chêng Chün says that, according to what he heard from *Lao Chün*, the attempted preparations of the Gold Fluid and the Divine Medicine should never be made in small mountains, where there are no real gods but spirits of trees and stones, aged things of ten thousand years, and bloodthirsty demons. These are devils who work not for the good but for the evil of man. They attempt to lead seekers of the *Tao* astray into temptation. The seekers should protect themselves and their retainers against these devils who may do harm to their medicines. In preparing good medicines, medical men of today guard against the sight of chickens, dogs, children, and women, lest the efficacy of their medicines be destroyed by the evil sight of these things. Likewise, dyers guard their goods from the sight of the evil-eyed, lest the beautiful tints be spoiled. What wonder then that the great medicines of the gods should be closely guarded? That is the reason why seekers of the *Tao* since ancient times do their compounding not in ordinary but in famous mountains.

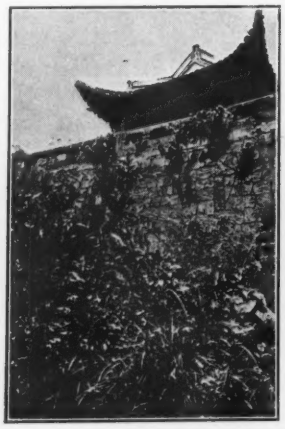
Ko Hung names twenty-seven mountains which are "fit for profound meditation and the compounding of medicines." Besides these "there are large islands which are next in order as places good for the preparation of the medicines" (he names six), and, since "the famous mountains of the central part of the country are inaccessible," he names eight which are accessible.

Concerning his own instruction in the art and concerning his attitude toward it, our author writes as follows.

It was *Tso Yüan-Fang* who, in the midst of profound meditation in the *T'ien Chu Shan* (Sky Pillar Mountain), was given volumes of the divine books on the Gold Medicine by some spiritual being. It was then the close of the Han dynasty (206 B.C. to 220 A.D.) when the land was rife with disturbances. So he fled across the river to come south with the idea of practicing the *Tao* in some famous mountain. From him my great uncle, *Hsien Kung*, received the *T'ai Ch'ing Tan Ching* (Book on the Supremely Clear Medicine) in three volumes, the *Chiu Ting Tan Ching* (Book on the Nine Furnace-Pot Medicines) in one volume, and the *Chin I Tan Ching* (Book on the Gold Fluid Medicine) in one volume. My great uncle in turn passed the books on to his disciple, *Chêng Chün*. *Chêng* was too poor to buy the necessary medicines for the compounding. I had been serving him as a disciple for a long time when we went to the *Ma Chi Shan* (Horse Footstep Mountain). There, at an altar especially erected for the purpose and with an oath, I received the book, some magical formulas, and the "Unprinted Magical Formulas." This last book was not known to be in existence until *Tso Yüan-Fang* gave it to my great uncle, who gave it to *Chêng Chün*, who in turn gave it to me. No other *Tao-shih* ever knew of it.

It has been more than twenty years since I got the books. Being poor I could only lament the want of means to make trial of the compounding. Yet there are those who have caskets full of gold and mountain-piles of money and know nothing of this art of immortality. They would not believe it even if they heard about it. How unfortunate for these people! Just as one would feel the insipidity of ordinary food only after having tasted a well-flavored dish, and sense the smallness of hillocks only after having seen the *K'un Lun* Mountain, so would one look down on the common recipes after having learned of the *Chin Tan*. ...

Since my youthful days I have had a liking for the art. I



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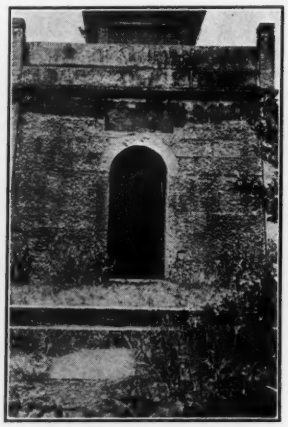

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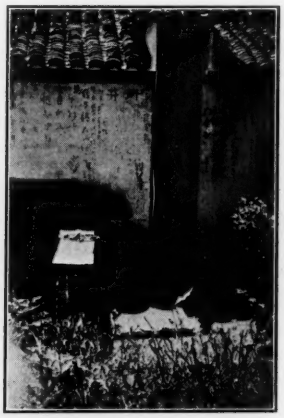

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travelled all distances and braved all hazards in my eager search for the truth. Whenever I succeeded in obtaining some unusual piece of information, I would feel gladdened at heart despite people's ridicule.

Not that I want to be known to the world through a book of strange thoughts and fanciful imaginings, but that for the sake of those among people of the future who will appreciate, I am writing this—knowing that all those of later times will be of inferior caliber. Just as the highest degree of *Yang* (Positiveness) will not revive what is decayed and the greatest mind will not be able to enlighten the most stupid, so books are comprehensible only to those who understand and things are valuable only to those who can appreciate. Give a bow of decoration to a farmer, and he will use it to chase birds away from his farm; give an emperor's robe to a southern barbarian and he will wear it to carry wood. They are simply ignorant. What else can be expected of them?..

Although I come from a family of high officials, I have no ability to manage affairs of state. Yet I could have attained fame and high official rank if I had followed the footsteps of my kinsmen who, although far less accomplished than I, have risen high in officialdom. For the sake of writing and compounding the Divine Medicine for the attainment of immortality in far-away mountains, I have left behind me my people and worldly honors. People of the world look askance on my abandonment of officialdom and on my isolation from the mass to take up the labor of farming. Some even say that I am out of my mind. But it should be remembered that the *Tao* and the affairs of the world are incompatible. How could I seek for the *Tao* without abandoning worldly affairs? When sure of his convictions, one acts accordingly with determination, unaffected by praise or by blame, by encouragement or by dissuasion from others. I write of my intentions so as to make them known to men of the same mind of the future. Men of determination who come after me will have to make sacrifices similar to mine.

The taking of the medicine converts the user into a *hsien*, a supernatural immortal endowed with marvelous powers so like those of the *jinni* of the Arabian Nights that we wonder whether the Arabic word, *jinn*, may not be derived from the Chinese, *hsien*.

The second medicine is called *Shen Tan* (Divine Medicine) or *Shen Fu* (Divine Charm) and confers immortality on the eater in a hundred days. He will be able to walk in fire and water uninjured. With this medicine smeared on the soles of his feet he will be able to walk on water. The eating of three knifebladesful of the medicine will kill off all sorts of worms in the body to the end that the eater will be free from all diseases. ...

The eighth medicine is called *Fu Tan* (Latent Medicine). It brings immortality to the eater on the very day that he eats it. The keeping of a quantity of the medicine about the size of the kernel of a date fruit will ward off all evil spirits. Doors with words painted in this medicine will keep off all devils, spirits, thieves, robbers, tigers, and wolves.

The ninth medicine is called *Han Tan* (Cold Medicine). Whoever eats a knifebladeful of it will become an immortal in a hundred days. There will come angels and fairies to wait on him. He will be light of body and will be flying on wings. ...

He who has his left hand painted with some of the Black Medicine admixed with a little water will be able to get whatever he desires.

If one desires to disappear at will, to foresee the future, to tell fortunes, to have eyesight covering thousands of miles, and to be an immortal, he needs only to partake of a knifebladeful of the Yellow Medicine. ...

KO'S HILL AT THE WEST LAKE, HANGCHOW. THE TABLET SHRINE AT THE LEFT

To compound the medicine of *Liu Shêng*, *Tan* admixed with the juices of the *Ti Ch'u* herb, the *Ch'u* tree, and chrysanthemum flowers is heated for thirty days and then ground to a powder. A year's eating of this medicine will bring a long life of five hundred years. If the eater be an old man he will be rejuvenated beyond recognition; if a youth, he will not grow old. ...

The medicine of *Han Chung Chung* is made by cooking honey and *Tan* in a sealed vessel. He who eats it will have his life prolonged, the strength of his eyesight improved, and no shadow cast from his person when standing in the sun.

Ko Hung discusses the cost of preparing the medicine and adds that the process is successful only if the batch is a large one.

True it is that the Nine Medicines are the best of the *hsien* medicines. Yet the materials for their compounding are quite numerous. They are easily procurable only in large cities which have good facilities for communication, but are not to be obtained at other places. Furthermore, in the compounding of the medicines, the fires should be tended for tens of days and nights with industrious application and close adjustment, which is a great difficulty. The compounding of the Gold Fluid is much easier. There the only thing which is difficult is to get the gold. One pound in the old measure is equivalent to two in our contemporary measure. Such a quantity of gold would cost only some three hundred thousand cash. The other auxiliary materials are easy to procure. In the compounding no fire is required. All that needs to be done is to have the mixture in a *Hua Ch'ih* (Flower Pond) for the necessary number of days. A total expenditure of four hundred thousand cash will make an amount large enough to transform eight persons into *hsien*. Just as no wine is formed by the fermentation of small quantities of rice, so small quantities of materials will not be able to interact to give the medicine.

There cannot be a greater mistake than looking superciliously upon practical applications of science. The life and soul of science is its practical application, and just as the great advances in mathematics have been made through the desire of discovering the solutions of problems which were of a highly practical kind in mathematical science, so in physical science many of the greatest advances that have been made from the beginning of the world to the present time have been in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind.—LORD KELVIN

METALS *and* ALLOYS *in the* CHEMICAL INDUSTRY

FREDERICK A. ROHRMAN

Michigan College of Mining and Technology, Houghton, Michigan

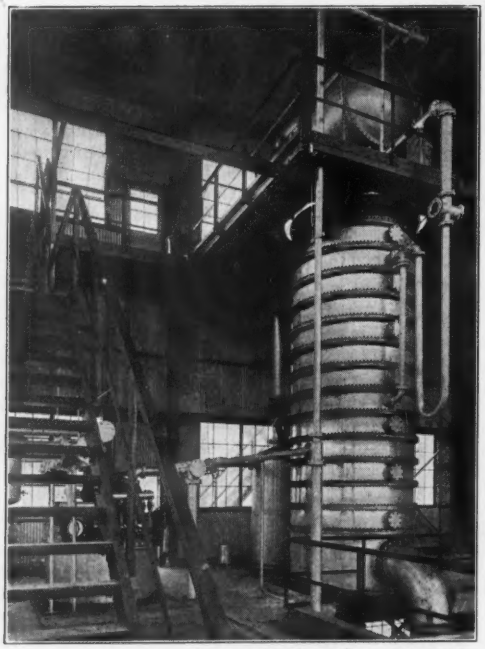
III. NON-FERROUS METALS AND ALLOYS

ALUMINUM

Aluminum is a comparatively new industrial metal. Despite this and the fact that it does not resist a majority of the more corrosive solutions, it enjoys a unique position among the corrosion-resisting metals. Its light weight and good physical properties make it very desirable for those solutions which it resists.

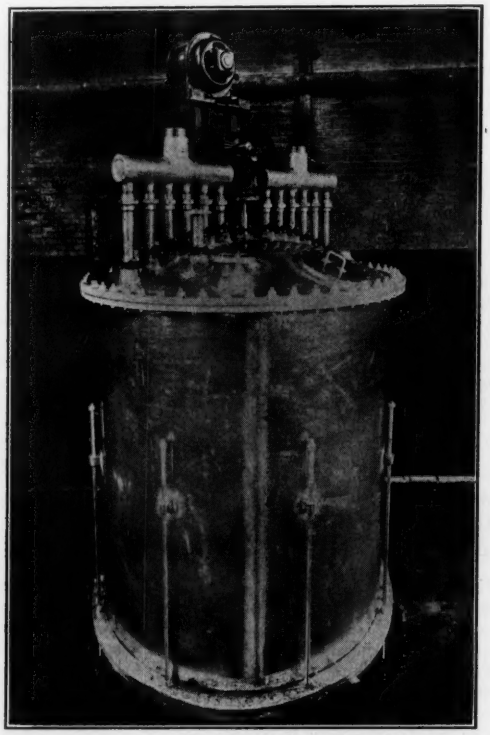
The oxide film which forms on aluminum protects the underlying metal from further attack. The speed with which this protective oxide film forms on the metal is remarkable.

Aluminum is used for nitric acid equipment, chiefly at the higher concentrations and at lower temperatures. It vies with copper for the honor of handling acetic acid. The great advantage it possesses over copper is that it can be used in the presence of dissolved oxygen or air while copper is slowly corroded. It is not recommended for acetic acid solutions which contain any appreciable quantities of formic acid, as the latter acid reacts with the metal. It is then recommended for purer acetic acid solutions containing dissolved oxygen to any extent and for apparatus which has to be used intermittently. Figure 9 shows a huge fractionating column and apparatus designed for acetic acid.



Courtesy Aluminum Corp. of America

FIGURE 9.—LARGE ALL-ALUMINUM FRACTIONATING COLUMN FOR ACETIC ACID



Courtesy Aluminum Corp. of America

FIGURE 10.—1280-GALLON ALUMINUM AGITATOR FOR ROSINS

Since aluminum salts are colorless and non-toxic, the metal can be used for processing substances and materials which would be ruined by slight contamination from other metals and alloys. For this reason aluminum is used for manufacturing many food products, oils, and varnishes. It is often used with the common fruit juices and acids, such as lactic and malic acids. Figure 10 shows a 1280-gallon aluminum agitator for rosins.

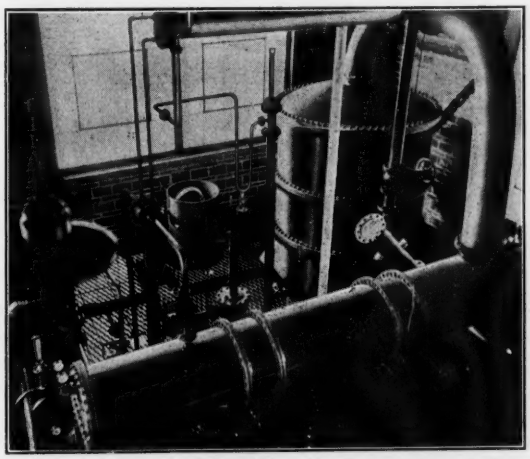
The presence of sulfates and chlorides is inimical toward the resistance of aluminum to various solutions; consequently nitric or acetic acid containing these anions will generally corrode the metal. Aluminum is not recommended for alkalis because of its amphoteric tendency to combine with them. It has been used to a great extent for handling beer and milk.

Small percentages of copper, silicon, manganese, etc., have been added to aluminum in order to improve its physical properties. As a rule the alloys of aluminum do not show the general resistance of the pure metal. Since this metal can be prepared quite pure and since pure metals are more resistant to corrosion than impure metals, it is possible that the purer metal will enjoy a greater use in the future. The writer has found exceptional resistance toward all the strong mineral acids by the purer metal.

COPPER AND ITS ALLOYS

Copper is one of the oldest known metals. Its service in the chemical industry was, and still is, important. Many of the newer metals and alloys have replaced copper, but it still may be classed as one of the important metals in this connection. The ancient Romans called copper "meretrix metallorum," for reasons apparent to the modern chemical plant operative who has occasion to observe its behavior with certain corrosives.

This metal is classed with the noble metals because of its low position in the electrochemical series, although it does not possess the chemical resistance expected from that position. In most corroding media it is slowly corroded in the presence of air or oxidizing agents due to their depolarizing action and the ease with which soluble oxides are formed. It is therefore used in those processes where such action does not predominate. Figure 11 shows copper and copper alloys as used in modern continuous distillation equipment for acetic acid.



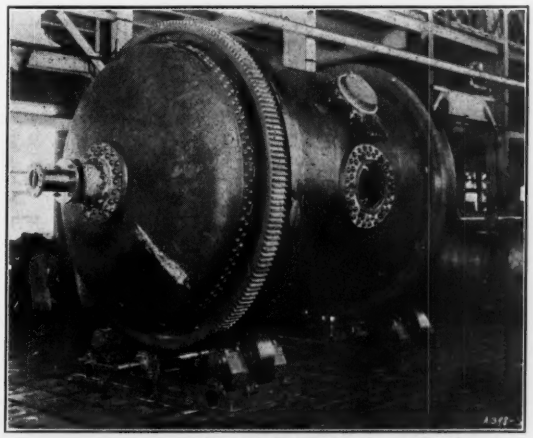
Courtesy The Vulcan Copper and Supply Co.

FIGURE 11.—MODERN COPPER DISTILLATION UNIT FOR ACETIC ACID

The pure metal has very little competition in equipment construction designed for the fermentation and alcohol industry. The ease with which it may be fabricated into complicated equipment and its good heat conductivity give it advantages over other metals and alloys. It is used for processing acetic acid and many of the fatty acids in the absence of air. The wood distillation industry employs it for apparatus in conjunction with the distilling and treating of pyroligneous acid and methyl alcohol. It is used in the construction of equipment for turpentine, wood oils, and resin.

The apparent non-toxicity of copper salts makes it useful in the manufacture of food products as well as beer and liquors.

Copper is rarely recommended for use with the stronger acids, salts, or alkalis. Ammonia solutions dissolve it readily. It is only slowly attacked by sea water and weak brines.



Courtesy Buffalo Foundry and Machine Co.

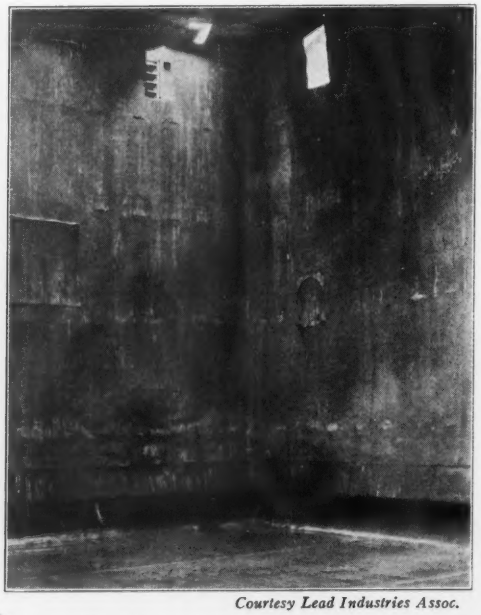
FIGURE 12.—DIGESTOR FOR RECOVERING FURFURAL FROM OAT HULLS. (CONSTRUCTED OF EVERDUR)

There are over two thousand alloys of copper containing zinc, tin, aluminum, nickel, silicon, iron, phosphorus, and many other alloying agents. Useless as many of these alloys are for the chemical industry, others are found to be serviceable for many of the common corrosives. The alloys of copper generally possess better physical properties than the pure metal. The uses of these alloys in the chemical industry are too diverse to mention. Figure 12 shows a large digestor constructed of "Everdur" (copper 96%, silicon 3%, and manganese 1%) for the purpose of recovering furfural from oat hulls.

LEAD

The use of lead dates back to the Roman era, when it was used for water piping. Since the advent of the sulfuric acid industry lead has possessed a unique position among the acid-resisting metals, being one of the few metals capable of resisting sulfuric acid solutions.

Lead is probably the purest metal used in the chemical industry and because it can be easily and economically produced in such a pure state it finds considerable usage. It possesses physical properties that are both advantageous and disadvantageous; it is soft and malleable, characteristics which permit ease in working but which demonstrate its lack of strength and resistance



Courtesy Lead Industries Assoc.

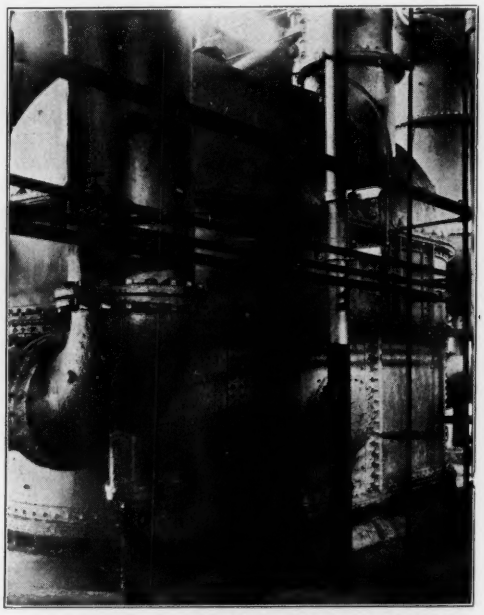
FIGURE 13.—UNUSUAL PHOTOGRAPH OF THE INSIDE OF A LEAD CHAMBER

to shock and impact. If lead is alloyed with 3–10% antimony, called hard lead or regulus metal, most of the physical properties are improved with very little decrease in chemical resistance. Very few other alloys of lead find use in the chemical industry. Recently lead-lined pipe and equipment made of steel have appeared on the market. By this ingenious combination great strength and chemical resistance have been combined. The lead lining in such equipment is from one-eighth to one-quarter inch thick.

The resistance of lead to sulfuric acid is due to the formation of an impervious, adherent film of lead sulfate which protects the underlying metal. The presence of sulfuric acid in some of the lead-dissolving acids, such as hydrochloric, renders the metal much more resistant. Lead is resistant to sulfuric acid at concentrations below 80% in either hot or cold solutions. At the higher concentrations and with oleum, lead shows very little resistance, probably because of the formation of the soluble acid sulfate. Lead is also resistant to phosphoric acid and to hydrofluoric acid, but strangely enough, not to a mixture of these acids; thus it does not completely resist hot solutions of crude phosphoric acid containing fluorides.

The sulfuric acid industry has been the greatest user of lead equipment. In the lead-chamber process for manufacturing this acid, lead is used extensively. Figure 13 shows a most unusual view of the interior of a huge chamber lined with sheet lead where the combination of steam, oxides of nitrogen, and sulfur produces the first stages of sulfuric acid. This photograph is of a unit which has produced acid since 1899 and is still in good condition. Figure 14 illustrates a coke-plant saturator made of lead-lined steel used in conjunction with ammonium sulfate recovery.

The production of phosphoric acid also has necessitated the use of lead in many stages of the wet process. It is chiefly used at the primary stages of the wet process when the phosphate rock and sulfuric acid are allowed to interact. Lead table tops for laboratories are common installations for school and industrial laboratories. In the electroplating and electrorefining



Courtesy Lead Industries Assoc.

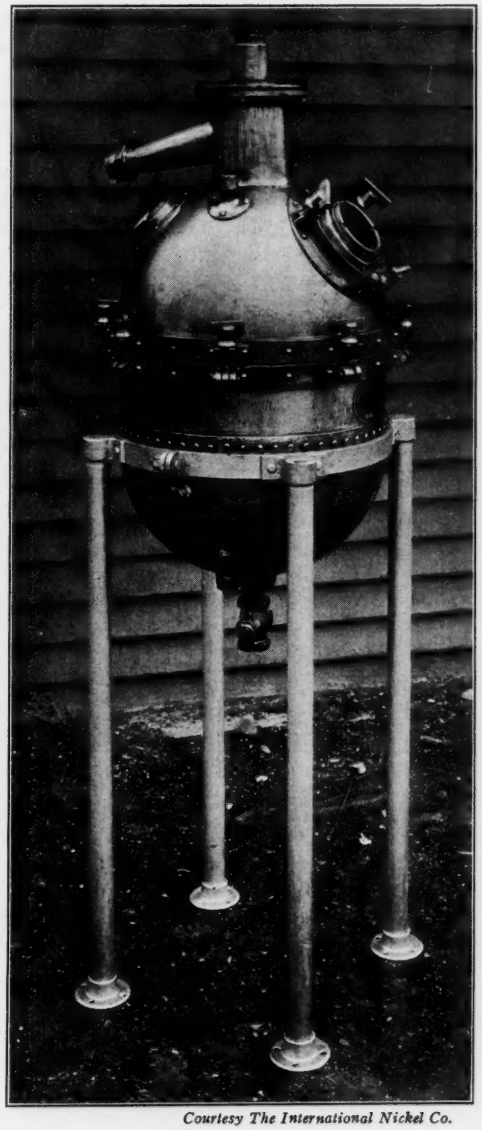
FIGURE 14.—COKE-PLANT SATURATORS CONSTRUCTED OF LEAD-LINED STEEL

of metals lead is used to a great extent for the lining of electrolytic tanks. Its use in the lead storage cell is common enough.

NICKEL AND ITS ALLOYS

Nickel may be considered as one of the newest of the metals in the chemical industry. Its excellent physical properties as well as its general chemical resistance place it in an enviable position. Its resistance may be ascribed to the ease with which it builds up protective oxide films in the presence of various corroding media.

Wide as is its use in the chemical industry, one can say that its chief uses are in handling and processing caustic, sodium chloride, and various organic chemicals.



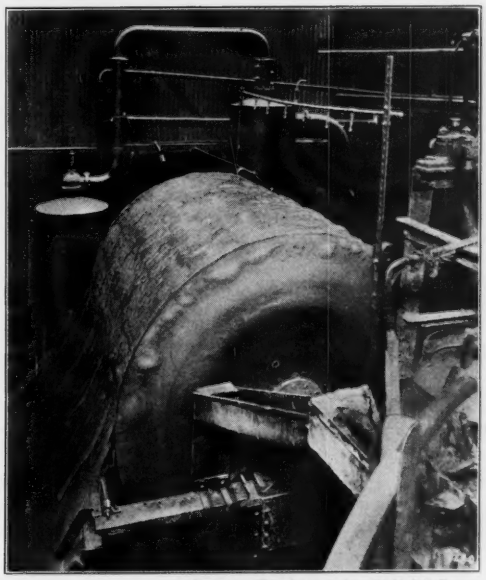
Courtesy The International Nickel Co.

FIGURE 15.—PURE NICKEL STILL FOR PROCESSING PHENOLIC RESINS

When iron or steel is used with strong caustic solutions there is often the danger of caustic embrittlement (another name for intercrystalline corrosion). Nickel is not subject to this type of corrosion under such conditions, consequently it is the more desired in the construction of equipment for handling caustic solutions. The fact that this metal is only slowly corroded by dilute solutions of hydrochloric acid has encouraged its use for the construction of pickling tanks, although Monel metal is preferred. A great deal of this metal is used in conjunction with the digestion, evaporation, and transportation of dyes and their intermediates, essential oils, and foodstuffs. Figure 15 shows a nickel steam-jacketed still for the purpose of processing phenol. Nickel is not affected by the phenolic resins; consequently, much nickel equipment is used for these materials. The Edison storage cell makes use of nickel electrodes. The metal is only slowly dissolved by most acids. The future for nickel as a corrosion-resistant material looks very bright.

The non-ferrous alloys of nickel are as important as the pure metal, if not more so. The most important alloys are divided into two classes, the acid-resisting and the heat-resisting alloys. In the former class the most important is Monel metal, containing approximately 67% nickel, 28% copper, and 5% other metals.

Monel metal has probably as extensive usage as any metal or alloy for resisting various corroding media. Its good physical properties and ease of fabrication make it exceedingly attractive for equipment manufacture. Its use is very common in the dye industry, in salt water, brines, and in the manufacture of organic and pharmaceutical chemicals. Figure 16 shows a



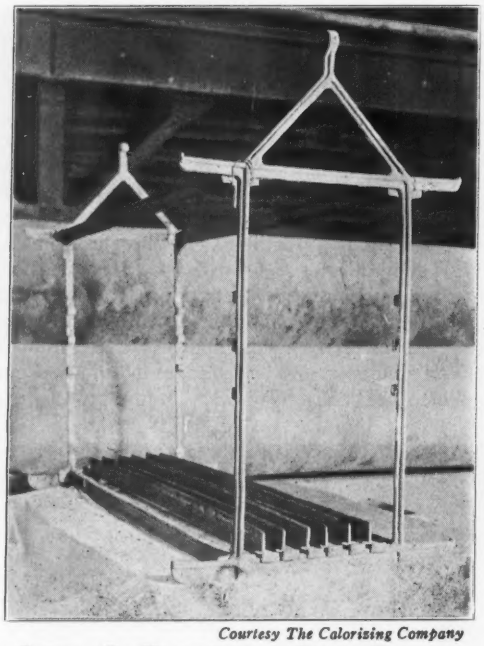
Courtesy The International Nickel Co.

FIGURE 16.—ROTARY FILTER FOR CAUSTICS. FILTER CLOTH MADE OF MONEL METAL

filter for the removal of spent lime from caustic. The filter cloth is made of Monel metal.

As previously mentioned, the alloys of chromium and iron, and nickel, chromium, and iron possess heat-resisting characteristics. In many respects the straight nickel-chromium alloys, and those low in iron such as Nichrome, Chromel, and Q-Alloy possess as good heat resistance but better physical properties at high temperatures. Thus, while a 28% chromium-iron alloy has a tensile strength of 80,000 lb./in.^{2} at room temperature and an 80% nickel-20% chromium alloy 120,000 lb./in.^{2}, the former will have a tensile strength at

1800°F. of only 1500 lb. and the latter 12,000 lb. Figure 17 shows a heat-resisting nickel-chromium-iron alloy rack for supporting ceramic ware in firing kilns.



Courtesy The Calorizing Company

FIGURE 17.—HEAT-ENDURING CALITE RACK FOR BAKING CERAMIC WARE

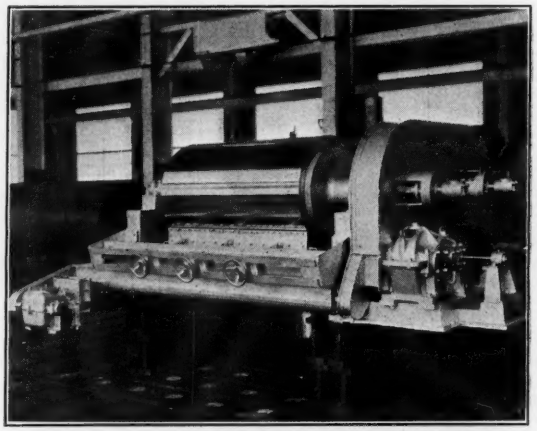
MISCELLANEOUS METALS AND ALLOYS

To cover this section thoroughly would require pages of information and data. Just where one should mention one alloy and leave out another is indeed controversial; however, no paper of this type would be complete without mentioning tin and zinc. Both these metals are used for plating and covering more corrodible metals, and both metals, especially tin, are used directly in the manufacture of many fine chemicals and pharmaceuticals. Tin is often used for water-distillation apparatus. The alloys of these metals with copper and nickel are very common and have found application in many phases of chemical manufacture.

Figure 18 illustrates the use of a chromium-plated drum drier for certain salt solutions. The hard, smooth chromium surface resists both erosion and corrosion. The use of pure chromium as equipment is very rare.

A number of important alloys consist essentially of nickel and chromium with varying quantities of molybdenum, tungsten, copper, and iron. The most important of these alloys are the Hastelloys, Illium, the La Bour alloys, Pioneer metal, and Inconel. These alloys have found the widest of uses. Pioneer metal as well as the La Bour alloys has been used in the manufacture of phosphoric acid. Illium is most commonly known as the metal used for the construction of bomb calorimeters.

Among the rarer metals, silver is the most important. It is used as a lining or in the plated form. Because of its high cost it can only be used in those processes where it is absolutely necessary to prevent contamination or equipment destruction. The photographic chemical industry uses probably more silver than all the other industries combined. Silver is also used in a few installations for the processing of organic acids, dyestuffs, and pharmaceuticals. Tungsten and tantalum possess desirable corrosion-resisting properties and are finding more uses every day.



Courtesy Buffalo Foundry and Machine Co.

FIGURE 18.—CHROMIUM-PLATED DRUM DRIER FOR DRYING CERTAIN SALT SOLUTIONS

CONCLUSION

It can be seen that considerable progress has been made in combating corrosion, "the big bad wolf" of chemical manufacture. A few years ago no metals were satisfactory for handling hydrochloric acid, hot crude phosphoric acid, and hot gases like SO_2 and SO_3. Today these materials are in contact with many different alloys that are not appreciably attacked.

There is very little doubt that newer processes and the production of newer chemicals on a more extensive scale will place extra demands upon the metallurgist for more resistant metallic materials. There is no reason for a pessimistic frame of mind, however, because the possibilities in the alloy field have only been touched and the chemist's knowledge of passivity has been very meager. The march of knowledge and experience goes on toward better metallic materials of construction. A later paper will cover the use of nonmetallics in the chemical industry.

ACKNOWLEDGMENT

The writer wishes to acknowledge the editorial assistance of Dr. Ella Wood of this institution and the cooperation of the many alloy and metal fabricators who made this paper possible.

TEACHING *and* STUDYING CHEMISTRY: *A* SENSATIONAL, SEDATE, *and* SOCIAL STUDY *and* SPORT*

RALPH K. STRONG

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NEWS DISPATCH: NEW COLLEGE STUDY! *Blankville, February 20, 1935.* Progress of education: a course for women who wish to gain experience in refereeing, scoring, and timing basketball and swimming meets has been inaugurated at the University of X.

DISPATCH FOR FUTURE RELEASE: NEW COLLEGE STUDY! *Blankville, date undetermined.* Progress of education: a course for teachers who wish to gain experience in refereeing, scoring, and timing chemistry meets has been inaugurated at the University of Q.

The former authentic except for the names of the city and university, the latter predicted. Both sensational.

NEWS DISPATCH: OLD COLLEGE SPORT! *Dashville, August 15, 1934.* National track meet: the University of Y has appropriated $20,000 to defray the expenses of competing athletes so that all parts of the United States may be represented at the meet.

NEWS DISPATCH: NEW HIGH-SCHOOL SPORT! *Writerville, May 4, 1934.* The sixth annual state contest for high-school chemistry teams is being held today throughout the state of R. Teams, determined in size by the enrolment in chemistry classes, are writing at their home schools, and the announcement of the winning team is awaited with intense interest as in previous years.

Two authentic dispatches. Honest, commendable, somewhat sensational.

Those who are familiar with the work of Edward Williams Morley are probably informed of the difficulties as to equipment and space which were overcome in his classical experiment on the composition of water. O. F. Mabery (*24*) said of him: "Such examples of devoted application to the expansion of knowledge concerning the fundamental forces of Nature as that of Dr. Morley's [whose work remained for 30 or 40 years 'unequaled for accuracy and thoroughness'] ... are greatly needed as an inspiration to the present generation. For with the aid of all the modern appliances the present worker must understand, first of all, that there never has been and never will be but one way to overcome the resistance of natural forces—by the application of persistent and well-directed labor."

The work of Pierre and Marie Curie constitutes another example of the overcoming of difficulties as to equipment and space. Mme. Curie once said (*6*) that their classical work on the separation and examination of radium could have been done in two instead of four years with proper facilities.

"The progress of any science," said Lord Curzon (*8*), "will always depend upon the character and ability of the men who devote their life to it."

We have passed to the sedate!

What have those of high standing in the community of learning to say concerning the *aims* and *methods* of *teaching* and *studying* chemistry?

The method of the lawyer in preparing a brief, namely, by the citation of case after case, is the method of science. We shall follow that method by selecting from many and varied authorities.

AIMS

Lavoisier, 1789: Every science consists of three things, (1) the facts which form the subject matter, (2) the ideas represented by those facts, (3) the words in which those ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea; and the idea ought to be a picture of the fact.

Ruskin: The work of science is to substitute facts for appearances, and demonstrations for impressions.

Mellor: The nomenclature of a science, that is, the group of technical terms peculiar to that science, is of vital importance. It is virtually impossible to separate the nomenclature from the science itself. . . Without facts science can do nothing; they are the foundation and building stones of the whole superstructure... The facts must be accurate or the whole edifice will be unstable (*26*).

Our First Aim: Proficiency in the use of the precise language of the science, and acquirement of its facts by persistent and well-directed labor.

Agassiz: Facts are stubborn things until brought into connection with some general law.

Herbert Spencer: The organization of knowledge is much more important than its acquisition.

* Contribution to the symposium on Lecture Demonstration *vs.* Laboratory Instruction conducted by the Division of Chemical Education at the eighty-ninth meeting of the American Chemical Society, New York, April 25, 1935.

Thomas Hobbes: The main purpose of science is the tying of facts into bundles.

Lord Rayleigh: Science is nothing without generalizations. The introduction of order and coherence facilitates retention.

Bowman: From an enormous mass of facts science must comb out the accidental and discover that which has significance, that which is recurrent, that which seems to relate cause and effect (*2*).

J. Arthur Thompson: When our aim is to get a grip of the scientific method, we are more likely to succeed by settling down to the thorough study of some one order of facts than by an intellectual ramble through the universe.

Our Second Aim: The organization of significant, recurrent, related facts into generalizations by observation and reasoning.

Korzybski: In science opinions are tolerated when and only when facts are lacking... When a subject is spoken of as a science it is understood to include (1) a knowledge of an enormous number of facts, (2) a large body of natural laws, (3) many fertile working hypotheses respecting the causes and regularities of natural phenomena, (4) many helpful theories held subject to correction by further testing.

Curtis: Refinement in the technic of analyzing phenomena constitutes the sole difference between the scientific and the popular method of drawing conclusions (*7*).

Our Third Aim: Generalizations rationalized into tentative hypotheses and tested theories held subject to further testing.

A. Lawrence Lowell: The goal is not the passing of the examination but the mastery of the subject (*23*).

Joel H. Hildebrand: The difficulties of the student are not concerned with the simple matters of fact so much as with general principles, methods, and points of view (*16*).

Langmuir: The methods are the important thing; the method of thinking, the method of using fundamental knowledge—these are essential (*21*).

Karl Pearson: The true aim of the teacher must be to impart an appreciation of method and not a knowledge of facts.

Charles W. Eliot: There are four essential processes of the educated mind: (1) observing accurately, (2) recording correctly, (3) comparing, grouping, and inferring justly, and (4) expressing the results of these operations with clearness and force.

Our Fourth Aim: Conscious, studied effort to ascertain the methods best adapted to accomplish the previously expressed aims.

METHODS

Liebig: At Giessen all were concentrated in the work and this was a passionate enjoyment. [Giessen, it will be recalled, was the first laboratory opened for systematic instruction in chemistry—by Liebig in 1824.]

Tilden: Liebig made many discoveries in chemistry but his great and permanent service to the world... consisted in showing how chemistry should be studied and how it should be taught (*32*).

Editor, Chemistry & Industry, 1932: The suggestion has been made ... that chemistry will only be put upon a proper footing in the university when a chair is established worth £5000 a year and the art of chemistry practiced by Liebig and his contemporaries is once more duly taught (*10*).

Murlin: Science ought to furnish the simple unaffected pleasure of finding things out for oneself (*28*).

Editor, Industrial and Engineering Chemistry, 1931: Education is earned by hard work and unless students in their tender years are skilfully taught discipline, methods of study, and how actually to work, there is no foundation developed upon which a satisfactory career in higher education can be based (*13*).

Powers: The major objective of a liberal education in chemistry is to teach an interpretation and appreciation of the truths of chemistry, and, in some measure, to train in intelligent usage of chemical products (*30*).

Willstätter: Main stress should be laid on training for independent ability (*33*).

Conklin: In science it is necessary to see and handle actual materials and processes in order to appreciate their significance.

Our First Method: Individual acquisition, by the student, of information and skill.

Cannizzaro, 1872: It often happens that the mind of a person who is learning a new science has to pass through all the phases which the science itself has exhibited in its historic evolution (*4*).

Goethe [who was a chemist as well as a man of letters]: The history of a science is the science itself—the past is the key to the present (*14*).

Editor, Forum, 1934: No matter how forward-looking our schools may be they can never afford to throw overboard the experience of the past (*12*).

E. H. Johnson: A full appreciation of the science of the present depends upon a knowledge of the work and workers of the past (*19*).

Our Second Method: To familiarize the student with the historical evolution of the various parts of the subject.

J. S. Haldane: The basis of a sound education must be humanistic, and ... even the teaching of abstract sciences such as mathematics or physics should, through the history of these sciences or in other ways, be connected with human interest (*15*).

Editor, Chicago Daily News, upon the occasion of the dedication of the University of Chicago chapel, 1928: Educational institutions do not and cannot limit themselves to the teaching and advancement of science, pure or applied; the spiritual and moral values are even more important to the human race ... than are the triumphs of the intellect or the material comforts resulting from those triumphs (*11*).

John Dewey: The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind.

Millikan, 1928: We need science in education not primarily to train technicians for the industries, but to give everybody a little glimpse of the scientific mode of approach to life's problems and to give everyone some familiarity with at least one field in which the distinction between correct and incorrect is not always blurred and uncertain, and to let him see that it is not always true that one opinion is as good as another (*27*).

James R. Angell, Elihu Root lecture, 1934: What is really important is not so much the prevalence of accurate, up-to-date scientific knowledge as the ingraining, deep in the habits of thought of the people, of the practice of careful, critical, unemotional—even skeptical—analysis of every significant issue with a corresponding conservative process of inference and generalization, so that intelligence may have free play to make its fullest contribution to the changing social order (*1*).

Peabody: A greater gain to the world than all the growth of scientific knowledge is the growth of the scientific spirit, with its courage and serenity, its disciplined conscience, its intellectual morality, its habitual response to any disclosure of the truth (*29*).

Our Third Method: Recognition of subjective values. Methods for producing a standardized, factory-made, quantity-produced material not to be applied. The scientific habit of mind involves the development in the individual of (1) disciplined, accurate, critical, unemotional, skeptical power of observation, (2) logical and systematic thinking and reasoning, (3) qualities of integrity, persistence, decision, imagination, serious purpose, good humor, and enthusiasm.

Sullivan: For the ordinary student the chief charm of science is that it acquaints him not only with a new body of ideas but with new modes of thinking. He experiences a veritable growth of consciousness (*31*).

Editor, Bulletin of the Society for the Promotion of Engineering Education: The aim of education is to produce a man who can think straight, who can analyze problems correctly, so that a solution may be obtained, and who has confidence in himself and his results. To do this there must be a thorough training in fundamentals (*9*).

W. F. Hillebrand: It is far better that the student should learn to do comparatively few things thoroughly, mastering the whys and wherefores of every step, than a great many superficially and without acquisition of the underlying principles (*17*).

W. Libby, 1917: Very little advance in culture could be made even by the greatest man of genius if he were dependent for what knowledge he might acquire merely on his own personal observations.

Our Fourth Method: The individual executing his own accomplishment. Not how much, but how well.

Philip Cabot: What is needed is not so much the strengthening of the curriculum as of the staff, for, whatever the name of the course of study, the objective is always the same—namely, to teach a way of life. Men cannot teach what they do not know (*3*).

A. W. Hull: Is the best lecturer one who explains so lucidly that you are left with a comfortable feeling of understanding, or one who, out of the fullness of his experience, opens out before you the unattainable yet challenging expanse of the subject? (*18*).

A. D. Carlson: No one can really teach who has not three assets: dependable knowledge in his head, and vigor and charm in his personality (*5*).

William McPherson, presidential address, American Chemical Society, 1930: "One of the most difficult positions to fill in our departments of chemistry today, and to my mind one of the most important, is that which has to do with guiding the instruction of the students in the basic introductory course. Men adequately trained in chemistry more and more seem to think it beneath their dignity to have anything to do with the beginner, apparently forgetful of the fact that the great chemists of all time regarded the introductory course as being of so much importance that they were unwilling to trust it to anyone other than themselves (*25*).

H. Le Chatelier: Many years ago Taine said that the systematic study of the dominant features of his subject was the essential characteristic of the true artist (*22*).

H. M. Jones: Teaching is an art, and can be managed only by an artist. An artist is a man of rigid intellectual discipline exercised in a field of which he is the master; he has sharp edges and colorful personality; he has bite, vigor, prejudice, information, determination, and he will not, if he be a true artist, tolerate flabby work. He is an intense specialist, to whom his peculiar interest is as the breath of life in his nostrils; an expansive and electric being whose talk is individual, rich, authoritative. These are the true teachers (*20*).

Tilden: The creation of a school of thought requires originality as well as learning in the teacher, intelligence in the taught, and a sympathetic relation between professors and students. These are more important than buildings and appliances.

Our Fifth Method: The student—intelligent, receptive, skeptical with decision. The teacher—possessing learning, originality, vigor, charm, furnishing guidance without dogmatism. The relation between student and teacher—reciprocal, sympathetic; well-received direction on the part of the student; well-directed coaching on the part of the teacher.

W. Lee Lewis: Chemistry is a sport as well as a profession, and therein lies the lure.

Nietzsche: To him who works and seeks in her, science gives much pleasure; to him who learns her facts, very little.

R. K. Strong: Chemistry is a game, and like every other fine sport has its rules which must be clearly understood and faithfully observed, in order to be abundantly appreciated by its participants. Therefore, learn well the rules of the game!

Murlin: We have encouraged our young men and women to rejoice in physical conquest. Have we taught them to rejoice equally in mental conquest?

Our Sixth Method: To treat chemistry as a sport as well as a study, thus lending zest to its pursuit.

PRACTICE

A student enters our class for the first time. He is an individual. He finds a definite seat assigned. Thereafter, vacant seats are noted—there are seldom any—mainly that we may know whether or not ignorance is due to absence.

The first meeting is social in character. There is some talk about words and language, about numbers and measurements, about attendance and work being expected. All with good humor but without frivolity.

At the second class meeting there is performance of lecture-table experiments by the instructor, thus beginning immediately the cultivation of attention and observation, and the recording and relating of information.

Before beginning individual work in the laboratory the group is instructed in what is to be done and shown how it is to be done, and informed that progress rests with the individual—that, no matter how apt or inept the worker, individual work is expected. And that the first consideration is not *how much* can be done but *how well* it can be done.

Reports on special topics are early expected but are not demanded. We demanded at one time but have found that voluntary work is more productive and more enjoyable. After consultation with the instructor a topic is selected. The student then reads about the subject, after which he submits an outline or plan. When this is approved in individual consultation he writes the report, if a library subject or a local study, or performs the experiment, if a laboratory topic.

Frequent written tests are given at regular intervals. These are not graded but are examined and discussed with each student during the laboratory period. When

the test is satisfactory or excellent the student is so informed, and when unsatisfactory the test is returned for revision.

The sequence of topics:

Part A. Emphasis on considerations of *matter*.

I. *Burning.* The transition from alchemy to the experimental basis of chemistry. Of exceedingly great importance in domestic living, in transportation, and in industry.

II. *Decomposition and composition.* Method of discovering practical chemical reactive units. Composition of water and carbon dioxide, two of the most important chemical and biochemical substances.

III. *Common gases.* Comprehension of the significance of IV. *Symbols, formulas, and equations* demands a knowledge of common gases as objective entities, and their composition and general behavior. Study also methods of preparation, and individual properties of the gases.

V. *Generalizations and theories* as to the behavior and constitution of molecules and atoms *en masse* and individually. (*a*) Dalton, Bunsen, Mendeléeff, up to 1895. (*b*) Röntgen, Moseley, Aston, Urey. (*c*) Becquerel, the Curies, Rutherford, Soddy, the Joliots, Lawrence.

VI. *Solutions and crystals.* Ordinary solutions; sugar; Raoult. Electrolytic solutions; salt; Arrhenius, Debye and Hückel. Pseudo-solutions; starch; silicic acid. Crystals from solution. Precipitation and solution. Other crystals in laboratory and in nature. Laue, Bragg.

Part B. Emphasis on considerations of *energy*.

VII. *Electrochemical considerations.* Electrolysis of sodium chloride. Electromotive force, and oxidation-reduction. Chlorine element and the halogens.

VIII. *Photochemical considerations.* Photosynthetic reaction. Carbon, element, and organic compounds.

IX. *Chemical equilibrium.* Temperature, pressure, and concentration effects in relation to (*a*) the natural rate of chemical reactions, (*b*) catalyzable reactions, (*c*) state of equilibrium. Nitrogen and sulfur elements.

X. *Thermochemical considerations.* Temperature and quantity of heat. Combustion and electrothermal reactions. Thermal oxidation and reduction. Metallurgy of iron. The elements: Cr, Mn, Fe, Co, Ni, Cu, Ag, Zn, Cd, Hg, Sn, Pb.

XI. *Geochemical considerations.* Rocks, minerals, soils. Silicates and aluminosilicates—portland cement, bricks, pottery, glass. Fertilizers. The elements: B, Al, Si, Ti, P, As, Sb, Bi.

XII. *Alkali-acid considerations.* Résumé of properties. Calcium compounds of nature, and the versatility of their application. Sodium compounds and their variety and frequency of occurrence. The elements: Na, K, Mg, Ca, Sr, Ba.

SUMMARY

1. Chemistry is chemistry, whatever the personal objective and whatever the application. The discussion concerns chemistry as a science course and not an appreciation course.

2. Chemistry is at one and the same time a sensational, sedate, and social study and sport, appealing to many and compelling to some.

3. There must be some individual laboratory work, no matter how inept the student, no matter how much trouble for the teacher, no matter how great the demand on the institution. The aim is not how much, but how well, therefore, individual progress and at varying rates. If objection be raised to this, it is met by simple arithmetic, "the mother of safety and the foundation of science"; small institution, 30 to 50 students, 1 to 2 teachers; large institution, 300 to 500 students, 10 to 20 teachers; it's all the same, large or small. The "work of art"—the student—depends largely upon the "artist"—the teacher. Mechanized, factory methods do not produce citizens of whom we are proud, nor those who will support a rational advancement of society.

4. Chemistry is a science; the teaching of chemistry is an art and demands an artist. It is not "Lecture Demonstration *versus* Individual Laboratory Method" but "Lecture Demonstration *plus* Individual Laboratory Method," in amount depending upon the individual. "One no more learns the art of working nor makes any true progress in scientific work by listening to the professor than one gains skill and muscle in gymnastics by watching the strong man at a circus"—and Montaigne might have added that no one gains skill in basketball or swimming by watching games and meets.

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POPULAR CHEMICAL EDUCATION *by* RADIO*

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A program answering chemical questions by radio indicates a wide audience and an avid interest on the part of the public. This interest extends from how to apply chemistry in cleaning, spot-removal, etc., to why things work. Such a popular audience is a virgin field for chemical education, not of the type that teaches chemistry as such, but of the applications of chemistry. A rapid expansion in the number of listeners over a period of a few months indicates public acceptance of the program. Such education must naturally be incidental to popularity of style of the material but as education is no less real.

✦ ✦ ✦ ✦ ✦ ✦

ALTHOUGH the authors have had direct contact with and have supervised certain radio broadcasting programs for some eighteen months, the subject of this paper is primarily concerned with one such program over Station WOR under the title "Science in Your Home." The broadcaster on that program is Dr. Kurt W. Haeseler, with occasional guest speakers.

Radio is normally viewed as a medium for entertainment, but a second thought shows that it is used for educational purposes as well. Educational use might be further subdivided into direct educational efforts, such as language classes and indirect educational efforts when tangible information is broadcast.

It is probable that use of the latter type of program is increasing and no doubt will increase further, provided the program is adjusted to the audience. Since the audience is a sampling of the general public, it is wise to avoid the use of the term "educational," as that seems to be a synonym for "dry and uninteresting" in the mind of the average person. However, if your approach is cautious and you do not frighten your listeners away before you have had a fair hearing, you will find an audience of a size undreamed of in connection with any previous method of approach.

Possibly the principle to be recommended is that of the barker at the circus—arouse curiosity and interest first, then do what you will. Whatever one may think about the contents of the book, the fact that "100,000,000 Guinea Pigs" was a best seller shows that people can be interested in scientific factual information related to everyday problems. Scientific achievements

* Presented before the Division of Chemical Education at the eighty-ninth meeting of the American Chemical Society, New York, April 26, 1935.

are given more and more space in the daily newspapers, and over 100 papers receive daily news releases from *Science Service*. Even the men of science receive more attention. Whether they find this desirable or not is beside the point. At least it indicates a growing awareness of matters scientific on the part of the public.

A rather general misconception which should be corrected is that chemistry is a study of dangerous materials, that chemicals are substances that explode, or that burn your hands, or that eat holes through fabrics. Chemistry should be interpreted in a much broader sense. Our thesis is that if the housewife learns something of the chemistry of salt and soap, and such homely things, she will find them more interesting to use and will, perhaps, be able to use them to better effect. To teach people some of the practicalities of science so that it will serve them in their everyday tasks is an important field of education in which little has been done. With the advent of the radio, new and far-reaching opportunities are afforded.

Data on the potential size of a radio audience are available. The figures which follow are for a 5000-watt station with antennæ near Newark, N. J. The method employed in making a survey of the broadcasting range was to send special mobile equipment throughout the area surrounding the station. Measurements of the intensity of transmission received at all points in the area were registered on electrical instruments. This process was followed until the exact points where the quality of reception became impaired were discovered. Such points determine accurately the limits of the effective broadcast coverage. The potential radio audience was determined by a count of the radio-equipped homes in the specific area covered, as determined by the United States census. This figure was then increased by the percentages which represent the increase in home radio ownership for each state from the period of the last census, April, 1930, to January 1, 1934, as determined by an analysis made by the Columbia Broadcasting System in coöperation with radio manufacturers, wholesalers, and dealers. The number of families owning radios was then multiplied by the average number of people per family in each state. This gave the potential radio audience in the reception area. The total potential audience for this 5000-watt station was estimated at over 15,000,000 or about 85 per cent. of the population in the radio district.

While a fairly accurate estimate of a potential radio audience can be made, it is much more difficult to arrive at a figure for the *actual* number of listeners. Several methods are in use. Perhaps the best known is the Crossley method, named after its originator, who devised it to assist advertising agencies. This type of organization has developed a system in which radio listeners are interrogated directly by telephone. The person who answers the phone is asked what radio programs he listened to on the previous day. No programs or stations are mentioned by the inquirer. Sometimes the calls are made at three-hour intervals during the day. In this way certain definite areas are covered and the results are arranged statistically to show the percentage listening in at certain hours of the day, and the relative popularity of individual programs. The intention is to make enough inquiries to get a fair cross-section of the popular reaction. This method is known generally as the recall method.

A slightly different procedure is the coincidental system in which telephone inquiries are made as to whether the radio is in use at the time of the call and, if so, what program has been selected. A number of independent surveys made in the Cleveland area showed that between the hours of 7 and 9 P.M. an average of approximately 50 to 55 per cent. of the radio owners had their radios in operation.[1]

Still another method of estimating the size of a radio audience is by house-to-house inquiry. When this method is used, forms are usually supplied for the radio user to fill in, so that he can check programs heard and does not have to depend so much on his own memory.

Letters of response to certain programs, requests for free samples, and similar communications from those listening have also been used as general indications of the size of the audience. However, these means are not considered very reliable, as offers of a particular product usually appeal only to a special group of listeners. It is conservatively estimated that for every one of those who write in, there are 50 listeners who never write.[1]

A rather interesting experiment was made in which the size of the radio audience was estimated by the amount of electric current consumed by the radios in use. The experiment was carried out on a Sunday evening between 9.45 and 9.50, on the assumption that at that time current consumption is ordinarily fairly constant. An electrical engineer, Dr. Nevil M. Hopkins of New York University, with a group of those interested, visited the electric power station controlling the area being studied. While they were there to take down the readings of current consumption, the listeners to a certain program were asked to turn their receivers off for three seconds and then on again. It was calculated that 50,000 people were listening to that program at the time. This method seems to be rather promising.

An attempt is being made at the present time to establish a radio audit bureau similar to the audit bureau of circulation used by newspapers to study and analyze circulation data. Such an investigative bureau would entail considerable expense and would be supported mutually by advertising agencies, broadcasting stations, etc. No doubt this will be worked out eventually, but such an undertaking requires time.

On the "Science in Your Home" program, an endeavor has been made to present scientific information in lay terms. The treatment is not radically different from that of other subjects on the radio but is not par-

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[1] EDE, KENNETH L., *Printers' Ink*, October 26, 1933.

ticularly well known to chemists. The nature of the audience requires that the material be given popular appeal by stressing striking and easily understood features. It is indicated also that for maximum understanding of the spoken word, the facts one particularly wishes to present should be so interspersed with side comments that they do not come too close together. Quite naturally, the wording must not be that of the scientific treatise or even of the daily newspaper.

Programs, however impromptu they may sound, are completely written at least a week in advance. The broadcaster frequently varies the wording and on rare occasions passages are simply marked "*ad lib.*" The field of material is almost unlimited, as any application of scientific information to household problems is pertinent. Letters suggesting specific subjects to be covered or proposing specific questions to be answered are invited and these letters always receive replies, either over the radio or by mail. At the present time about 1000 letters a month are being received from listeners.

An attempt was made to ascertain the number of listeners to this program by means of three one-minute announcements in which free samples of a client's product were offered. This was first tried at a time when the program had been on the air for about four weeks. Some 600 replies were received. At a later date another free offer was made, this time of a different product which would, in general, appeal mainly to elderly people. Some 1300 requests were received within a week. Even at the conservative 50:1 ratio mentioned, this indicates an audience of over 60,000 for this program, educational in principle, even if not so labeled. It further indicates the probability that growth of the audience on this program was rapid.

While the program is planned primarily for the housewife, the letters which come in daily show that the audience is rather heterogeneous. All kinds of information are requested. Apparently, the public considers that a person with a certain amount of scientific training is able to answer any and all questions. One woman wrote in that her husband was injured in the war and that in consequence he takes pink pills which he buys from a druggist on Fordham Road, and she gave the exact location. She wanted to know if we could tell her where else he could buy the pink pills. Several have asked what makes the smoke in airplane sky-writing. One man wrote that he was a musician who played trumpet solos. He wanted something that would hold his false teeth in for at least two hours, as they sometimes fell out in the midst of his playing.

Great numbers of inquiries as to how to get rid of roaches and other insect pests, and how to remove all kinds of spots and stains, are received. Various individual problems have to be considered, such as how to mend a vase, how to re-finish a piece of furniture, how to keep the silver bright after it is polished, how to clean out a drainpipe, how to remove hard-water deposits from cooking vessels, and so on. The educational director of a Civilian Conservation Corps of 400 men in New Jersey wrote that they were listening in every day and requested copies of a certain script. Many requests for script copies are received, but as no provisions have been made for publication, these requests cannot be met.

Letters asking questions of a scientific nature often come from school children. One thirteen-year-old girl wanted to know whether girls could become chemists. This inspired a broadcast devoted to the life of Marie Curie. A boy of seven wanted to know whether there wasn't some way of bringing sunlight into his home, which was always dark. Frequently, letters come in from young amateur chemists who have chemical sets and want to know how to perform certain experiments. One boy wanted to know how to make an explosive; needless to say, he was speedily and emphatically discouraged in this ambition. Often children ask what schools to attend in order to fit themselves to become chemists or chemical engineers. They also want to know what books of a scientific nature to read.

On the occasion of the announcement of the award of the Nobel Prize to Dr. Harold Urey, the Swedish Consul General spoke on the life of Alfred Nobel; this program and the one devoted to the life of Madame Curie were deviations from the usual trend of the program material. Popular scientific news is available to us through *Science Service* news releases, and is introduced on occasion, when it pertains to the general subjects of the scripts. In such an event, it is not presented in newspaper style nor simply as a news broadcast.

Programs like that under discussion are not feasible without financial support; advertisers constitute the source of such support. At the present time commercial announcements are used with 60 per cent. of the broadcasts without too seriously reducing the quality or quantity of scientific material presented. From the viewpoint that the advertiser pays for the program in order to bring his product to the attention of the public, there need be no serious conflict, since, if the program interests the public, that is all the advertiser requires. One listener in asking a question even offered the side comment that she did not have use for the sponsored product but that if she did she certainly would use it. This would seem to indicate an appreciation by the public of the coöperative nature of the support of such a program; if the public supports the advertiser, he supports the program.

It is hoped that the broadcasting of material of a scientific nature will stimulate the interest of the average person in science. If he learns that science need not necessarily be relegated to textbooks, to the classroom, or the laboratory, but that it can be applied to everyday matters, he has taken a long step forward. When a person realizes that the purpose of obtaining education is not so much to acquire knowledge, as to acquire knowledge and then use it, it begins to take on a new meaning. We believe that a trend toward that realization is indicated in our correspondence.

UNDERGRADUATE ORGANIC LABORATORY CHEMISTRY

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IVB. APPARATUS ASSEMBLAGE

IN A PREVIOUS article* the function of the laboratory was asserted to be twofold. It should enable the student "*to learn*" certain facts and basic principles by means of first-hand experimentation, and it should provide adequate exercises to enable him "to learn *to do*." The successfully conducted laboratory course should provide opportunities both "*to learn*" and "to learn *to do*." It should offer a training that provides both for the development of a practical apparatus sense, and the acquisition of an appreciable dexterity in the assembling of simple laboratory apparatus.

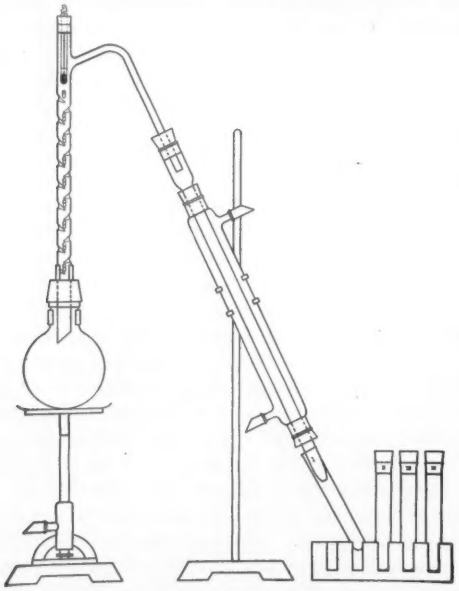

FIGURE 1.—SET-UP FOR FRACTIONAL DISTILLATION WITH A VIGREUX COLUMN

By "Apparatus sense" is meant that certain indefinable intuitive skill that enables one to visualize the particular type of set-up that is best adapted to a given procedure. It is this same intuitive ability, on the other hand, that enables the student to visualize the particular type or types of procedures that are carried out most advantageously in any given set of apparatus. As organic laboratory courses are usually conducted, very little emphasis is placed on the development of this very desirable and useful intuitive sense.

Most manuals give, perhaps, adequate drawings and illustrations of laboratory apparatus. However, they may be too generalized, and sufficient modifications and adaptations to meet given variations may not be included. This is evidenced by the fact that the average student seems to perform the successive exercises with an utter dependence on the particular drawing that is indicated for the given procedure. Consequently, at the close of most courses, the average student cannot pass an examination on the particular set-ups that would be used most advantageously for a given list of simple preparations. To be sure, there is and must be a limit to what can be included in any given course, but it does seem that the student of science should, during his undergraduate days, show a higher degree of development with respect to what has been designated here as apparatus sense. While the author is concerned primarily with the teaching of organic chemistry, this same urgent need is doubtless felt in other branches of science.

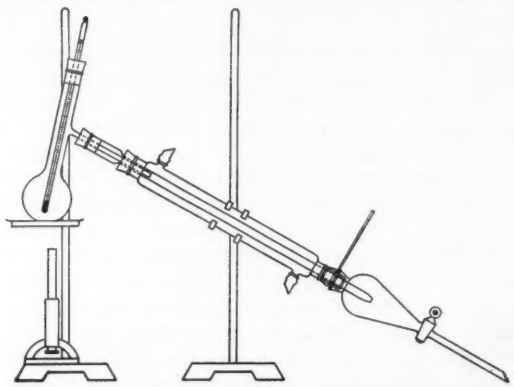

FIGURE 2.—"SET-UP" FOR THE PREPARATION OF DIBUTYL ETHER

Some time ago this organic division undertook the preparation of a complete series of placards† depicting simple laboratory set-ups. These are of convenient size for display purposes, measuring twenty-two by twenty-eight inches. About sixty-five of these placards have been prepared and more are in the process of

* DEGERING, E. F., "Undergraduate organic laboratory chemistry. IVA. Test-tube experiments," J. CHEM. EDUC., **12**, 316–7 (1935).

† This project was made possible through an F.E.R.A. grant.

preparation. At least one of these placards is always on display in an enclosed bulletin board at the laboratory entrance.

Photographs and lantern slides have been prepared of the completed placards. The four-by-five prints have been arranged to form a composite exhibit of organic laboratory set-ups. Each of these prints is accompanied by a short note descriptive of the particular procedure most applicable to the apparatus assemblage. This exhibit is always in evidence near the laboratory entrance. By means of these two exhibits, the passing students are faced with a large placard which silently describes a particular assemblage of apparatus and with a similar placard or set of placards that give a kaleidoscopic survey of the apparatus phase of laboratory organic chemistry.

The lantern slides that have been prepared from these drawings are used in part at almost every laboratory period. This affords the instructor an excellent opportunity to discuss with the group the reasons for the selection of a particular apparatus assemblage for a given procedure and the reasons for certain modifications and adaptations. This particular phase of the laboratory work is covered in the periodic examinations.

While much is to be desired in the extension and improvement of our teaching methods, the results in this particular direction, made possible through the acquisition and utilization of these additional teaching facilities, have been very gratifying.

*V A. THE USE OF LECTURE DEMONSTRATIONS**

THE laboratory instructor is constantly confronted with the problem of providing for his students the maximum possible facilities or opportunities "*to learn*" and "to learn *to do*." A valuable teaching aid, in this direction, is afforded by the use of lecture demonstrations. It is beyond the scope of this paper to argue the relative merits of lecture exhibitions of the art of doing as a substitute for regular laboratory work or vice versa. Instead, it is the unique combination of lecture demonstration experiments and regular laboratory exercises, in so far as we have been able to compare methods, that has given the most satisfactory results in the undergraduate organic laboratory work at Purdue. Lecture demonstrations can play an important rôle in the instructor's task of offering to his students favorable occasions "*to learn.*" No less important is the service to be rendered by providing the student with ample opportunities "to learn *to do.*" Such facilities are afforded by the use of adequate laboratory lecture exercises that exemplify proper procedure and correct technic.

To be a successful experimenter, one must be an artist. Like all artists, the experimenter must acquire a peculiar and characteristic technic. While the aptitude for any given art may be inherent in the individual, the particular technic that enables one to excel comes only through proper instruction and supervised practice. The beginning scientist, playing the rôle of the beginning artist, must be carefully instructed in his art and then properly supervised in his practice.

The simplest possible method of instruction in the art of performing experiments is, without doubt, by actual demonstration. If a U-bend of glass tubing is to be prepared, the proper procedure can be exemplified by the instructor in a very few minutes. The same information, adequately conveyed by use of words and drawings, would require much more time and effort. The average student might be tempted to duplicate the article prepared by the instructor in the lecture demonstration, but would find little incentive to test his skill by following the procedure outlined in words and drawings.

Suppose that the exercise involves any of the following processes: the softening of a cork in a press, the boring of a hole in a cork or stopper, the fitting of a piece of glass tubing with a cork or stopper, the fitting of a piece of glass tubing with a short length of rubber tubing, or any of a host of other common laboratory operations. For such assignments, one of the simplest and most effective methods of instructing the student in proper procedure and correct laboratory habits is the lecture demonstration. These specific illustrations have all dealt with what might be termed simple manual operations; but even greater opportunities lurk in the field of simple chemical procedures.

The simplest chemical procedures in the laboratory deal with test-tube experiments. It is perhaps the normal practice to assume that the average student knows how to carry out a simple test-tube experiment. Actually, very few students do. Our experience, with junior science and chemical engineering students, indicates that the average student is woefully lacking in the first principles of test-tube technic.† This apparent incompetence is responsible, in part, for our present practice of coördinating lecture demonstrations with regular laboratory work.

During the first half of the course about one-third of each period is spent in lecture demonstrations. The rest of the period is spent in the performance of regular laboratory exercises. This permits at least one or more illustrations of practically every operation that the student is called upon to perform in the course of his various experiments. Furthermore, it provides the good student with the desired opportunity of ac-

* Presented before the Division of Chemical Education at the eighty-ninth meeting of the American Chemical Society, New York, April 25, 1935. (Symposium on Lecture Demonstration Method *vs.* Individual Laboratory Work.)

† It is not intended, however, to imply that the fault lies in the freshman and sophomore years. What the student acquires, he acquires by means of constant repetition. There is doubtless something to be said against our entire method in that we make little or no provision for repetition.

quiring, through observation and practice, correct methods of procedure and proper laboratory habits. Periodic checks by the instructor during the course of the semester on the laboratory habits of his students, will materially aid in desirable developments along these lines.

Through the use of lecture demonstrations the student may be given the opportunity "*to learn*" and "to learn *to do*." Immediately following the lecture exhibitions he may be called upon to put into practice many of the things that he has observed. Such a coördination should tend to intensify the lecture demonstration. By repeated observation and repeated attempts to perform, the student may acquire, bit by bit, the finer elements of laboratory technic.

There is still another argument in favor of correlating lecture demonstrations with regular laboratory work. The average student load in most institutions is at a maximum. As a result, the efficient instructor must seek to impart a maximum amount of instruction, measured by tangible results, in a minimum of time.

This may be accomplished, with very satisfactory results, by use of the lecture demonstration-laboratory combination. During the lecture demonstration hour, the entire work of a normal laboratory period may be completed. The student may then spend the rest of the period in the performance of regular laboratory procedures. These may take the form of the preparation and assemblage of apparatus, the synthesis of typical compounds, or a study of the chemical properties of a given compound or a group of compounds. The work of a period and a half to two periods may be covered in a single lecture demonstration-laboratory session. During one such session the student will doubtless acquire more than he would during two normal laboratory periods.

The lecture exercises should be carefully coördinated with the regular laboratory work. Lecture demonstrations should be planned so that they will offer a maximum of information and yet give the student an adequate illustration of the art of doing. Obviously enough, the preparation of a justifiable lecture exercise in laboratory organic chemistry is both difficult and time-consuming. Lecture demonstrations that are properly coördinated with the laboratory experiments, however, justify both the extra effort and the additional expenditure of time.

*VB. TYPES OF LECTURE DEMONSTRATIONS**

IN THE previous discussion, arguments for the coördination of lecture demonstrations with regular laboratory work were presented. Having granted the advisability of such a coördination, one is immediately confronted with the problem of selecting appropriate material for such exercises.

The material for lecture demonstrations in the organic laboratory may be divided, for the purpose of this discussion, into four distinct groups. These may be designated as simple manual operations, easy laboratory preparations, laboratory exhibits of more difficult procedures, and test-tube experiments.

In any laboratory course it must be conceded that emphasis should be placed upon simple manual operations. One of the main objectives of the laboratory is to give the student an opportunity to learn to use his hands correctly and with a certain degree of dexterity. The process of acquiring correct manipulative practices involves both adequate instruction and correct practice. Adequate instruction in any manipulative exercise is doubtless best imparted to the student through the use of sufficient demonstrations, and the acquisition of dexterity is acquired through proper practice. In such simple operations as boring a good hole in a cork, experience has indicated that three or four repetitions may be required to convey the rudiments of the art to the average student. It is only by means of *repeated observation* and *repeated practice* that improvement in technic is assured.

In this class of demonstrations may be grouped a large number of ordinary operations. The most of these are so simple that the instructor is likely to err in assuming that his students are already familiar with the correct manipulative procedures. Is there any laboratory operation, one may ask, that is so simple that it does not justify one or more demonstrations at the hands of the instructor?

Usually, the first few days in the laboratory in any given course present ample opportunities to familiarize the students with the simple manual exercises. As more advanced experiments are encountered, demonstrations in the assemblage of apparatus afford an opportunity for repeated exhibitions of the correct procedures involved in these simple operations. In an exercise calling for fractional distillation, the instructor can well afford to take time to show his class how to assemble the apparatus. Three or four assemblage demonstrations during the semester should serve to illustrate adequately the correct manipulative procedures involved in the preparation of any given set-up.

The next phase of the problem is concerned with easy laboratory preparations. It is not to be contended that all easy preparations should be performed by the instructor. Such preparations as methane from chloroform, acetylene from calcium carbide, and formaldehyde from methyl alcohol, however, afford excellent opportunities for the instructor to illustrate correct procedures. The information conveyed to the student by adequate illustrations of the steps involved in these preparations will doubtless outweigh what the student might obtain through the performance of the exercises. The effectiveness of the lecture demonstration may be intensified by coördination with the laboratory work which immediately follows. If the instructor has shown

* Presented before the Division of Chemical Education at the eighty-ninth meeting of the American Chemical Society, New York, April 25, 1935. (Symposium on Lecture Demonstration Method *vs.* Individual Laboratory Work.)

the preparation of formaldehyde and the general properties of the aldehydes, then the laboratory period may be profitably devoted to the preparation of acetone and a study of the general properties of the ketones. If the lecture hour is devoted to the preparation and properties of acetylene, then the laboratory period may be spent advantageously on the preparation of ethylene and a study of the properties of the olefins. It is such a coördination of lecture demonstrations with regular laboratory work that has proved most satisfactory in our undergraduate organic laboratory course at Purdue.

More difficult procedures are best shown as an exhibit in the laboratory during the regular period. The preparation of ethyl iodide by the Adams* method, which involves expensive apparatus, may be carried out by the instructor or an assistant while the students are about their regular assignment. Casual observation of the preparation tends to familiarize them with the process. The preparation of zinc ethyl in a unit set-up, followed by the preparation of zinc diethyl in the following period, makes another impressive exhibit for the laboratory.†

Last but not least is the problem of test-tube exercises. A student should, if reasonably possible, acquire the art of performing test-tube experiments. This technic is best acquired, no doubt, by the joint use of lecture demonstrations and laboratory exercises. Such a practice affords the opportunity for the student both to observe how such operations should be carried out and to practice by means of first-hand experimentation. Such coördination also has the questionable advantage of decreasing the number of test-tube experiments that the student is called upon to perform. The question pertains to relative results. Will the student acquire more technic through the performance of a given number of test-tube experiments with no previous demonstrations, or through the performance of about half as many such experiments that have been coördinated with a similar number of test-tube exercises performed by the instructor? This question will of necessity have to be answered by the instructor concerned. It should be remembered, however, that the performance of too many test-tube experiments by the student tends to distract from his interest in the course with a consequent tendency toward carelessness in his test-tube procedures. Lecture demonstrations of test-tube experiments, on the other hand, tend to emphasize the importance of such routine.

In conclusion, arguments have been presented to indicate that lecture demonstrations in the undergraduate organic laboratory may be devoted advantageously to simple operations, easy laboratory preparations, laboratory exhibits of more difficult procedures, and test-tube experiments.

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* ADAMS, ROGER AND VOORHEES, V., "The preparation of alkyl iodides," *J. Am. Chem. Soc.*, **41**, 789–98 (1919).

† MCCLEARY, RUSH F. AND DEGERING, E. F., "The secondary reactions in the preparation of zinc ethyl," *Proc. Indiana Acad. Sci.*, **43**, 127–31 (April, 1934).

PROFESSOR C. W. FOULK

READERS who have delighted in Professor Foulk's informal photographic portraits of prominent chemists and who were entertained by his account of the making of the Ostwald-van't Hoff photograph [J. CHEM. EDUC., **11**, 355–9 (June, 1934)] will probably welcome presentation of a portrait of the author himself. For the snapshot reproduced herewith we are indebted to Paul K. Winter, a recently graduated student of Dr. Foulk's and "a great admirer of his."

PITTSBURGH ANNOUNCEMENTS

NEW SUMMER COURSES

The University of Pittsburgh will offer two new courses during the 1936 summer session which begins June 29th. The first is a course on "New Developments in Biochemistry," which will include vitamins, hormones, and other food accessories, as well as micro procedure with the Linderstrøm-Lang apparatus. Dr. C. G. King will be in charge.

The second course will be on "New Developments in Chemical Theory." It will include the newer thought on radioactivity, nuclear chemistry, the structure of the atom, the Debye-Hückel theory of ionization, the Brønsted theory of acids and bases, etc. Dr. A. L. Robinson will be in charge.

Courses in quantitative organic microanalysis, chemical microscopy, and full-year undergraduate courses in inorganic, organic, analytical, and physical chemistry will also be offered, as well as graduate courses to meet the needs of applicants.

AMERICAN CHEMICAL SOCIETY MEMBERSHIP AWARD

The staff of the Chemistry Department in the University of Pittsburgh have selected Mr. John J. Griffith, a Senior in the course leading to the Bachelor of Science degree in chemistry, for the American Chemical Society membership which is awarded annually to the student who has the best record during his first three years of residence.

John Griffith graduated from the Avalon High School in June, 1932, with honor and was awarded a half scholarship in the University of Pittsburgh. In the examinations which are conducted by the Allegheny County Civic Club for the Buhl Foundation, he ranked second highest and was awarded the balance of his tuition for his Freshman year.

Since attending the University, Mr. Griffith's exceptional record has resulted in his election to Phi Lambda Upsilon, national honorary chemistry fraternity.

SOME USES *of the* POLAR MOLECULE CONCEPT *in* ELEMENTARY CHEMISTRY

SIDNEY J. FRENCH

Colgate University, Hamilton, New York

The recently increasing knowledge of dipoles and dipole moments together with the simplicity of their qualitative interpretation, suggest the use of the concept of polar molecules in elementary chemistry.

The concept follows naturally from a discussion of sharing electrons in covalent compounds and the transfer of electrons in electrovalent compounds. It leads to a better general understanding of the problems of symmetry in molecules, coördination valence and compounds, association in liquids, solubility, melting and boiling points, and the structure of solids.

+ + + + + +

WITHIN the past few years, the terms dipole and dipole moment have taken on meanings important and useful to the chemist. While the mathematical considerations in the derivation of dipole moments could find little space in an elementary course, the qualitative meanings of the terms are so simple of comprehension and so useful in correlating many chemical facts that they might well be introduced early and used as fundamental concepts. The introduction of these concepts necessitates the addition of very little new materia' beyond that usually considered in elementary principles. For purposes of consideration, the discussion is divided into three parts, namely: electrovalence and covalence, dipoles and dipole moments, and applications.

ELECTROVALENCE AND COVALENCE

According to the fundamental theory of electronic structure, electrovalent* compounds are formed by the transfer of valence electrons from electropositive to electronegative elements as is illustrated in the following diagram:

$$A\cdot \longrightarrow :\ddot{B}:$$

In compounds thus formed, the ions are semi-independent units being attracted to oppositely charged ions by electrostatic forces. In the solid form, the ions take up definite positions alternating in the crystal lattice to bring about the greatest possible degree of electrostatic neutralization. In solution, the ions, though mobile, are still subject to similar though non-oriented forces and in addition, may be subject to immeasurable hydration effects.

On the other hand, covalent molecules are formed by the sharing of one or more pairs† of valence electrons as is illustrated in the following diagram:

$$:\ddot{A}\cdot \rightleftarrows \cdot\ddot{B}: \;=\; :\ddot{A}:\ddot{B}:$$

In such molecules, the atoms are definitely oriented with respect to one another and largely retain the original orientation and unitary character in solution. In the case of electrovalent compounds, then, we are dealing with ionic units, while in covalent compounds we are dealing with molecular units.

It is not always a simple matter to distinguish between electrovalent and covalent compounds, though extreme cases of each are easily identified. Many cases are known in which the compound appears to be covalent in the solid or gaseous form and electrovalent in solution. Other compounds, including weak electrolytes, are covalent in the solid form and both covalent and electrovalent in solution. It is, therefore, entirely possible in certain compounds for the molecule to pass from one form to the other when the environment is changed. The question naturally arises—are these changes more or less imperceptible gradations or is there a sharp break between the two types? The study of dipole moments has thrown considerable light on the question but has not finally answered it yet.

Some very general rules for predicting which binary compounds will be covalent and which electrovalent have been devised by Fajans (*1*). To interpret these rules properly, it is necessary to regard the atom or ion as a polarizable system in the sense that the electron shell can be deformed or pulled away from the core or nucleus under the influence of an electric field. Figure 1 suggests the idea of such polarization. An atom deformed or polarized in this way is sometimes spoken of as a temporary or induced dipole because the centers of the opposite charges do not coincide while under the influence of the field. For simplicity, a dipole might be pictured thus: $\boxed{+\ -}$

* The term electrovalent is used to describe ionized compounds; the term polar being reserved to describe non-ionized molecules having dipole moments.

† In a few instances, there is evidence that one electron can be shared.

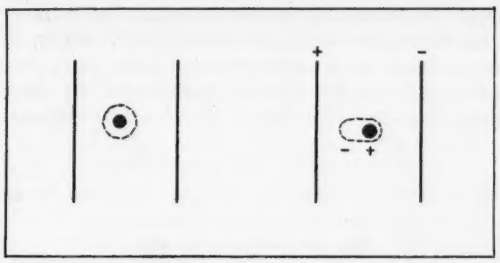
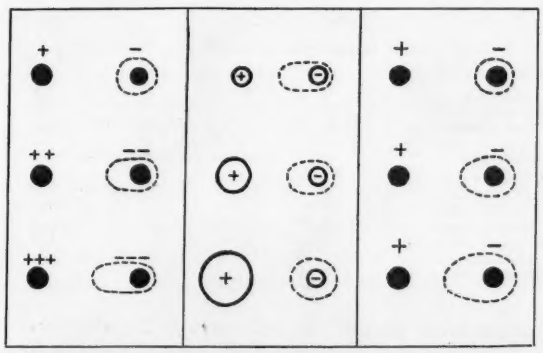


FIGURE 1.—POLARIZATION IN AN ELECTRICAL FIELD

According to Fajans' rules, a small positive ion should be able to approach a negative ion more closely than could a large one. It should therefore cause a greater distortion of the valence layer of the negative ion. If, in addition, this small positive ion has a high charge, *i. e.*, a valence of plus 3 or 4, its distorting ability should be even greater. Further, if the negative ion is large so that the valence layer is relatively distant from the nucleus, and if there are several extra electrons in the valence layer, *i. e.*, the ion has a high negative charge, it should be most easily distorted. If the distortion of the negative ion becomes sufficiently great, one or more pairs of electrons may become so much the property of the positive ion as to be shared by both ions, and a covalent molecule results. In brief, when the positive ion is small with a high charge and the negative ion is large with a high charge, covalent molecules result. Under the reverse conditions, the compounds are electrovalent. Figure 2 illustrates these ideas. Because the positive ions are small and because they carry an excess positive charge, the remaining electrons are tightly held and deformation is slight in case of positive ions.



Effect of Charge on Polarization of Negative Ion | Effect of Size of Positive Ion on Polarization of Negative Ion | Effect of Size of Negative Ion on Its Polarization

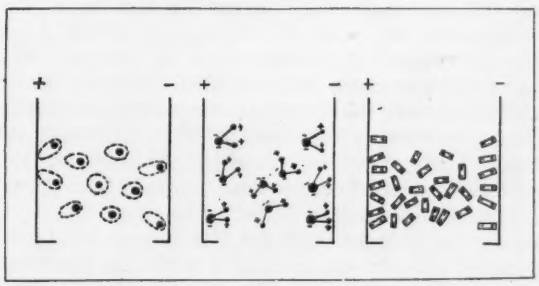
FIGURE 2

When Fajans' rules are applied to the periodic table, it becomes evident that the large monovalent alkali metals and the smaller monovalent halogens will have the greatest tendency to form electrovalent compounds. Since the heavier elements of a family have, in general, larger atoms, electrovalences will be more common among the heavy metals of high valence charge than among the lighter ones of similar charge. Thus, boron forms no binary electrovalent compounds, while aluminum with a larger atom forms compounds which appear to be covalent in the solid form and electrovalent in solution. Electrovalent compounds of metals with a valence of plus 4 are limited to the heavier ones (Pb and Sn) and then are found only in solution. No electrovalent compounds having negative ions with valences greater than -2 are known. All compounds of formula $A'''\ B'''$ are covalent.

DIPOLES AND DIPOLE MOMENTS

The original assumption in the theory of covalency was that the electron pair was equally shared by both atoms. However, general considerations including the above discussion and other lines of evidence lead to the conclusion that such is not the case. It is reasonable to expect that the more negative element in a covalent molecule will have the greater control over the shared pair. The only cases of equal sharing should be in the diatomic molecules of the elementary gases such as H_2, N_2, O_2, and Cl_2. If the electron pair lies closer to one atom than to the other, the molecule should be a permanent dipole. The question arises, is there any way of measuring the relative displacement of the shared electron pair away from a mid position? While several methods are available, they are somewhat complicated and their details need not be considered here. A qualitative consideration of one method must suffice.

If two metal plates are charged, one positively, the other negatively as in the case of a condenser, electricity can be stored up on the plates. If this process is carried out with a vacuum between the plates and later with a non-conducting liquid or a gas between, it is found that a larger amount of electricity is used in the later trial in order to obtain the same potential difference between the plates. In other words, it seems as though the liquid or gas has absorbed some of the electricity. At least three factors may account for this additional absorption: the atoms are distorted, the molecules are distorted so as to increase their polarity, the molecules are oriented with their negative ends toward the positive plate and vice versa. Figure 3 illustrates these effects.



Electronic Polarization | Atomic Polarization | Molecular Orientation

FIGURE 3

The third factor, molecular orientation, will only be present when the molecules are dipoles. Naturally, orientation in liquids or gases will be seriously disturbed by the Brownian movement. As the temperature is decreased, orientation will become more pronounced while the other effects are but little altered. As orientation increases, the amount of electricity absorbed also increases. It is therefore possible by using a number of different temperatures to determine the orientation effect alone and this is a measure of the charge of the dipole. Dipoles of high charge will orient more completely than those of low charge. The charge at one end of the dipole, in electrostatic units, multiplied by the distance between charge centers in the molecule, gives a value known as the dipole moment. ($e \times d = \mu$.)

The dipole moment for gaseous hydrogen chloride is found to be 1.03×10^{-18} e.s.u. When sharing is equal, the moment is zero. If we knew what the dipole moment would be were the electron completely transferred to the chlorine atom, we would be in a position to know how much the displacement of the electron pair from mid-position has been. This can be determined approximately by calculating the moment, assuming complete transfer. The electronic charge is 4.77×10^{-10} e.s.u. The distance between atomic centers is 1.273×10^{-8} centimeters. The calculated dipole moment ($e \times d$) would then be 6.08×10^{-18}. Since the actual observed dipole moment (1.03×10^{-18}) is only about one-sixth of this value, we may assume that the actual displacement of the electron pair from mid-position has been about 17% of the total possible displacement. Since all interatomic distances in covalent molecules are of the order of magnitude of 10^{-8} cm., we can say that the dipole moment itself is a rough measure of the electron displacement.

Interestingly enough, it has been found that few if any covalent compounds have dipole moments which would indicate an electron displacement of more than 20 to 25%. Does this mean that further displacement results in the formation of electrovalence? Does it mean that an electron pair from an ion must be pulled or distorted 75% of the distance to mid-position before the molecule becomes covalent?

We have no satisfactory methods for determining dipole moments of electrovalent compounds, but Sidgwick (*2*) has suggested a means for arriving at the approximate degree of distortion in a polarized ion pair by comparing the shrinkage in interionic distances when we pass from an A′B′ compound to an A″B″ compound, the elements being in the same period. The higher valences of the ions in the second compound should produce greater distortion and shorten the apparent distance between ionic centers. The actual shrinkage in distance is found to be about 9%. Assuming a similar shrinkage for A′B′ over an ideal non-polarized ion pair, we arrive at a maximum distortion value of 18% to 25%. Further distortion results in the formation of covalent molecules, for all compounds of formula A‴B‴ are covalent.

From this evidence it would seem that covalence and electrovalence are quite distinct. However, it is quite possible that intermediate cases may exist. Figure 4 suggests the relative positions of the valence electrons* in the four types of relations considered.

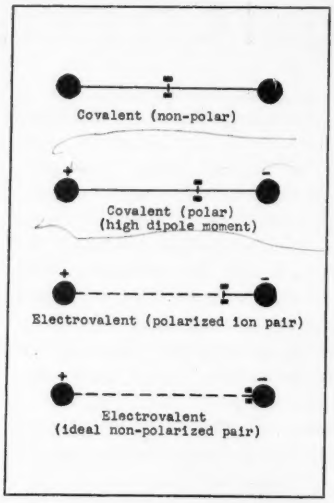


FIGURE 4.—TYPES OF MOLECULES

Until more evidence is available, the question of just where the transition from polar covalence† to (polarized) electrovalence takes place must remain unanswered.

Table 1 gives the dipole moments of a number of compounds, as well as the calculated moments for several individual links. In general, the dipole moment

TABLE 1

DIPOLE MOMENTS ($\mu \times 10^{18}$)

Hydrogen H_2	0	Arsine AsH_3	0.15
Nitrogen N_2	0	Water H_2O	1.85
Nitrous oxide N_2O	0	Hydrogen sulfide H_2S	1.10
Carbon dioxide CO_2	0	Hydrogen cyanide HCN	2.1
Carbon disulfide CS_2	0	Sulfur dioxide SO_2	1.6
Ethane C_2H_6	0	Silver perchlorate $AgClO_4$	4.7
Ethylene C_2H_4	0		
Carbon tetrachloride, CCl_4	0	*Links*	
Hydrogen chloride HCl	1.03	C=O	2.5
Hydrogen bromide HBr	0.79	C—O	0.9
Hydrogen iodide HI	0.38	H—O	1.6
Ammonia NH_3	1.50		
Phosphine PH_3	0.55		

is greater the greater the difference in the electropositive and negative natures of the elements in the com-

*Some authorities prefer to interpret dipole moments, coordination compounds, association, and molecular structure in general without reference to the electron since the true nature of the electron and its relation to the nucleus are still obscure.

Electronic formulas and models cannot be interpreted as literal pictures of molecules but they are of considerable value as mechanical aids and their use is justified so long as no attempt is made to attach exact physical meanings or values to them. They are to molecular structure what the "billiard ball" molecules are to the kinetic theory.

† The term "polar covalence," while not in general use, has been suggested by WILDMAN, J. CHEM. EDUC., **12**, 13 (Jan., 1935).

pound. From Fajans' rules it is possible to predict the relative dipole moments quite accurately. Thus, the moments of the hydrohalogen acids are in the order HI < HBr < HCl. The one salt, $AgClO_4$, included in the list has a moment approaching that which might be expected for a (polarized) ion pair. The appreciable, though small, solubility of the salt in the non-polar solvent, benzene, permitted the measurement of its moment, which was made by Williams and Allgeir in 1927. It might be anticipated that a double bond (four shared electrons) would double the moment of a single bond. Evidence seems to show, however, that the value for the double bond is more than twice the value of the single. Compare C—O and C═O.

As will be noted in the table, carbon tetrachloride has a zero moment while the link C-Cl has a high moment. The zero moment of carbon tetrachloride can be explained as a result of the symmetry of the molecule as a whole. If the carbon atom is placed in the center of a tetrahedron with the valences extending to chlorine atoms at angles of 109°28′, the moments of the several links will cancel one another and the total molecular moment will be zero. In a similar manner, it is found that many paradibenzene compounds have zero moents, where the substituted groups are themselves symmetrical. Thus, it is evident that zero dipole moment may be due to (1) equal sharing of electrons or (2) symmetry of the molecule.

The fact that carbon dioxide has a zero moment while C═O has a high moment indicates that the sum of the separate moments in CO_2 is zero, and the molecule must be symmetrical, with the atoms lying in a straight line. The tetrahedral model for carbon requires such an alignment. Similarly CS_2 and N_2O have zero moments. The fact that SO_2 has a rather high moment indicates that the molecule is unsymmetrical and has been interpreted as being, in part at least, a consequence of the dissimilarity of the two sulfur-to-oxygen bonds (four electrons shared with one oxygen atom and two from the sulfur shared with the other). The high dipole moment of water indicates that the molecule is not symmetrical and cannot be linear. If the four pairs of electrons around the oxygen atom are located as at the points of a regular tetrahedron, then the angle between the hydrogen atoms should be about 109°. All covalent molecules of type AB_2 with single bonds which have been studied so far have dipole moments. Figure 5 illustrates some of the points discussed above.

We have confined our attention chiefly to the simpler types of compounds in order to make the principles clear. In the more complex molecules, the situation is complicated by the fact that we know little as yet about the effect of one polar link on adjacent links. The fact that the moments of individual links can be calculated and that one group can be substituted for another in organic compounds has greatly aided in the study of the stereochemistry of such compounds and in the interpretation of their behavior.

To sum up, we may say that:

1. Polar covalences are characterized by having dipole moments.
2. The dipole moment is determined as $e \times d = \mu$ where e is the charge which has been transferred in e.s. units and d the distance transferred in cm.
3. The dipole moment is an approximate measure of the displacement of the shared pair of electrons from mid-position (in diatomic molecules).
4. There seems to be a definite break between polar covalence and electrovalence.
5. In compounds having zero dipole moments, the electrons are equally shared, or the resultant of the moments of several links in a symmetrical molecule is zero.

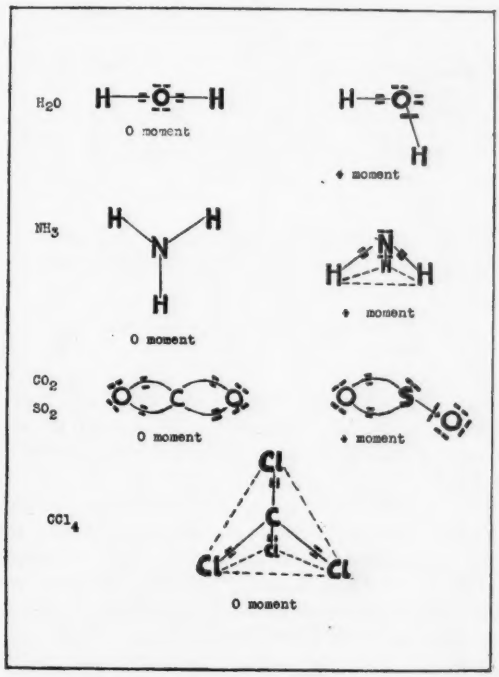


FIGURE 5.—SYMMETRY AND DIPOLE MOMENTS

APPLICATIONS

1. *Coördination.*

We have come to recognize a third type of valence having what is commonly called a coördinate link. In such a link, both members of the shared pair of electrons are donated by one member of the compound. The case may be represented as follows:

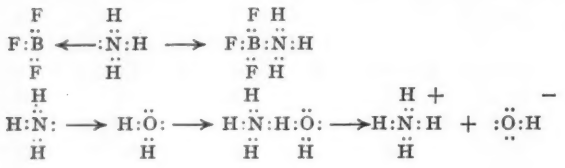
$$:\ddot{A}: \longrightarrow :\ddot{B}: \;=\; :\ddot{A}:\ddot{B}:$$

To all appearances, the product is identical with one formed by covalence.

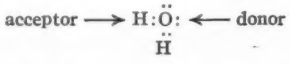
$$:\ddot{A}. \rightleftarrows :\ddot{B}: \;=\; :\ddot{A}:\ddot{B}:$$

However, there is considerable difference not only in the bond itself but also in the properties of the compounds formed and in the types of substances which may unite in each way.

One of the factors necessary for coördination is that one of the groups (A) shall have an unshared pair of electrons which it may donate while the other group (B) shall be short one or more pairs (has less than eight). But this is not all. If both groups were perfectly non-polar we should not anticipate union. It is also necessary that both groups be polar, having relatively high dipole moments. Even under such favorable conditions, coördination is largely limited to compounds of lower molecular weight. Two classic examples of coördination are those of boron trifluoride with ammonia and water with ammonia. All have high dipole moments. The unions are indicated below.



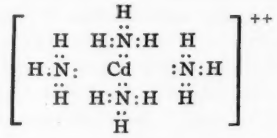
Water is rather unusual since it may act either as an acceptor of electrons or as a donor, as is indicated below.



It may therefore coördinate in two ways. The acceptor power of hydrogen varies with the magnitude of the moment of the H-X link, and only in the case of H-O (and H-F) is the magnitude great enough to permit hydrogen to act as an acceptor.* Likewise, the oxygen in water is a strong donor. We might say that a water molecule has two strong electrostatic hooks of opposite charge. In a great majority of cases, however, water coördinates as a donor through the oxygen atom rather than as an acceptor through the hydrogen atom.

Not only can water molecules coördinate with dipoles but also with ions, particularly positive ions. This gives rise to water of hydration in solid salts. In general, the smaller positive ions are more consistently hydrated than the larger ones, and those of high charge more consistently hydrated than those of low charge. Likewise, ions of high charge generally yield salts containing more molecules of water of hydration than do those of low charge. Thus, lithium with a small ion yields hydrated solid salts much more commonly than does potassium with a larger ion, while aluminum with a highly charged ion yields salts which are not only commonly hydrated but which also contain a large number of water molecules. Negative ions, because of their larger size and because they must coördinate with the hydrogen of the water molecule, are much less frequently hydrated than are positive ions.

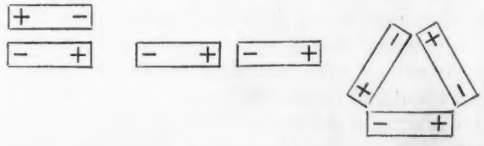
Ammonia, with a relatively high dipole moment, also coördinates readily with many positive ions, forming what are commonly known as complex ammonia ions. This coördination takes place most readily with ions having valences of one and two, relatively small sizes and high nuclear charges. Thus, Cd with a nuclear charge of 48 readily forms the complex $[Cd(NH_3)_4]$ illustrated below. In general, where complexes are formed, the monovalent ion coördinates with two ammonia molecules while the divalent ion coördinates with four.



2. Association.

In considering coördination, we have been dealing with compounds which obey stoichiometrical laws. We may now consider less exact phases of a similar type of electrostatic force.

It is well known that water as a liquid does not have the exact formula H_2O but rather $(H_2O)_x$ where x appears to have values of from 1 to 3. In other words, several molecules of water are grouped together. This association is readily understood when we realize that water molecules as dipoles are well equipped with both donor and acceptor hooks. The association might be pictured as follows:



It is a more or less indefinite and ill-defined grouping because of the kinetic activity of the molecules and groups. As the temperature falls, the orientation becomes more orderly and complete.

When a liquid boils, the molecules are separated from one another against the electrostatic attraction which tends to hold them together. We should therefore expect an associated liquid like water to have a high boiling point. Figure 6 shows the boiling points of a number of inorganic hydrides and methane.

The influence of high dipole moments and consequent association on boiling points is quite evident in comparing methane with hydrides of the other elements of the first period. Hydrogen fluoride is known to be associated in the gaseous form having the formula

* A number of American investigators, notably Pauling, Huggins, Rodebush, and Latimer, prefer to interpret association of water, formation of acid fluorides, and other phenomena in which bonding takes place through hydrogen, as due to the hydrogen ionic bond rather than to coördinate covalence with hydrogen acting as an acceptor. Since this paper is largely based on the interpretations of Sidgwick, no discussion of the hydrogen ionic bond is included.

$(HF)_6 \rightleftharpoons 6HF$. Ammonia is thought to be associated in the liquid state. In group VI, the influence of increasing molecular weights becomes predominant as the dipole moments become negligible, for, other factors being similar, both boiling and melting points increase with increasing molecular weights.

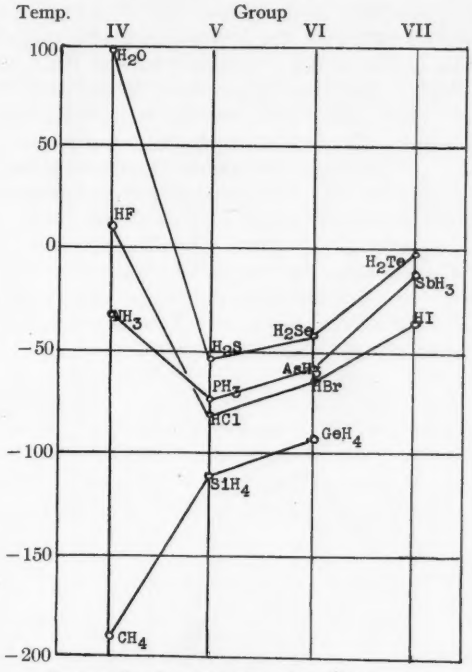


FIGURE 6.—BOILING POINTS OF HYDRIDES

Hydrogen, except when attached to oxygen, is a poor acceptor; consequently water is considerably associated and has a high boiling point. Organic liquids containing the O-H link have in general high boiling points and are associated liquids. This is most evident in the organic alcohols and acids.

3. Solubility.

In considering solubility, we must take into account dipole moments, donor and acceptor conditions, molecular weights, melting points, and other factors somewhat obscure. As a general statement, it may be said that solvents with high dipole moments should dissolve most electrovalent compounds unless the molecular weight and melting point are too high. As Hildebrand (*3*) points out, "The phenomenon of solution is essentially one of liquefaction; the molecules (*or ions*) are detached from a crystal lattice in each case to enter a 'society' of liquid molecules in which the forces may be very much the same as if the solid were melted to form its own liquid." To put the whole matter very briefly, we may use the old expression, "like dissolves like." We must, however, interpret "like" in terms of dipole moments, symmetry, molecular weight, melting point, etc. Figure 7, borrowed from Hildebrand (*4*), illustrates the probable mechanism of the solution of a salt in water.

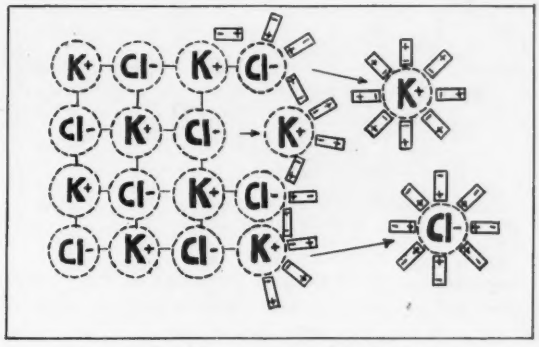


FIGURE 7.—MECHANISM OF SALT SOLUTION

In addition to being an excellent solvent for electrovalent compounds, water is a good solvent for polar organic liquids, particularly for those containing the O-H link. In this case, there exists in the solution an association between dissimilar molecules which, however, have similar associating powers.

Substances such as soaps and long-chain organic acids having one strongly polar end have considerable electrostatic affinity for water and are slightly soluble in it. The other end of the molecule with a hydrocarbon structure and little polarity has no affinity for water but dissolves in organic liquids of low or zero moment. Such molecules serve as excellent "bridges" or "anchors" to hold water and oil surfaces in close contact. Figure 8 illustrates the mechanism. Such compounds are known as emulsifying agents.

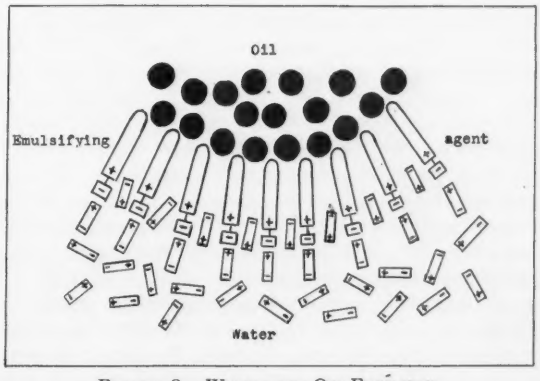


FIGURE 8.—WATER AND OIL EMULSION

As might be expected, water is a poor solvent for compounds of zero dipole moment since such compounds have no electrostatic "hooks" with which to hang on, and cannot penetrate the high electrostatic field around the water molecules. However, the occasion may arise in which a relatively large or long molecule having two strongly polar groups so placed that the resultant moment is zero might be soluble in water since each

polar group might act as a somewhat independent hook. The possibility is pictured in Figure 9.

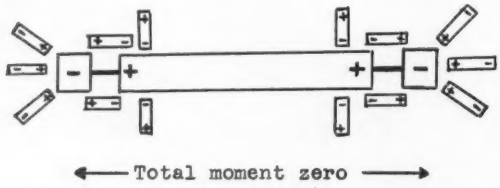


FIGURE 9.—SOLUTION OF POLAR MOLECULE OF ZERO RESULTANT MOMENT

Liquids having zero dipole moments should dissolve readily in one another since there is neither repulsion nor attraction. The situation is somewhat analogous to the mixing of one gas with another. Again, however, we must take into account the fact that the zero moment may be the resultant of several widely separated high moments.

4. Solids.

Since even such a substance as helium with its zero dipole moment, low atomic weight, and completely inert structure can be converted into the solid state at low temperatures, it is evident that there must exist a type of cohesive force quite apart from the electrostatic forces thus far considered. This force, apparently gravitational in nature, is known as the van der Waals force and is very small in comparison with the electrostatic forces involved in valence. It must, however, be taken into consideration in any discussion of solids.

Most solids have definite crystal lattices in which the ions or molecules are held together by some form of electrostatic force involving electrovalence, covalence, or coördination. Let us consider first the case of true electrovalent salts. X-ray analysis indicates that the ions occupy alternating positions in the lattice so arranged that no pair of ions can be considered a unit. Throughout the crystal electrovalent forces extend, in most cases, equally in all directions. Though directed, these forces do not hold the ions in as rigidly oriented positions nor as firmly as do the covalent bonds. Consequently, such crystals are relatively brittle though not extremely hard. To melt a solid of this type, it is necessary to supply sufficient energy to release the ions from their fixed electrostatic moorings. Naturally, since the forces are large, the energy required is considerable and the melting points of salts are relatively high. The melting temperature is, of course, influenced by the sizes of the ions as well as by the charges.

Passing now to the other extreme, we should expect strictly covalent molecules of zero dipole moment to have very low melting points since the forces holding the molecules together are of the van der Waals order. In ideal cases, the melting points should increase with increasing molecular weights. The rare gases most nearly illustrate the ideal case. In such solids, entire molecules occupy points on the crystal lattice. In cases where the zero moment of a complex molecule is the resultant of several high moments, electrostatic forces may also come into play and melting points should be, in general, higher.

We should expect the melting points of polar covalent compounds to be higher than those having zero dipole moments since the forces holding the molecules together in the crystal lattice are not only the van der Waals forces but also the residual electrostatic forces characteristic of dipole molecules. Other factors being similar, the melting points should increase with increase in dipole moment and molecular weight much as boiling points do. As the shared electrons are progressively displaced from mid-position, the forces holding the *molecules* together should approach those holding the *ions* together in a salt crystal.

Figure 10 is prepared from data collected by Biltz (*5*), and discussed by Clark (*6*) in "The Electronic Structure and Properties of Matter," **1934.**

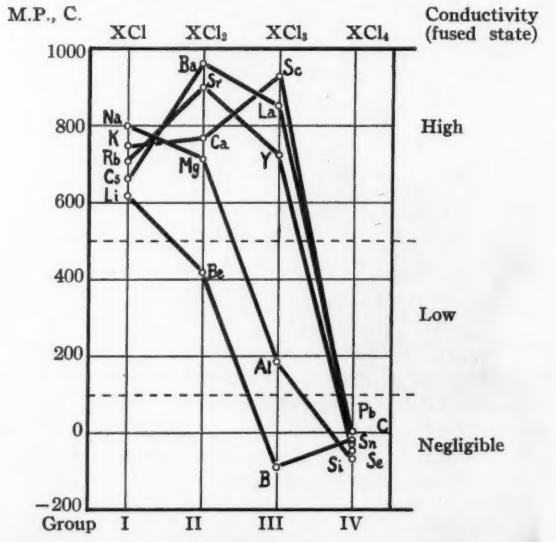


FIGURE 10.—MELTING POINTS AND CONDUCTIVITIES OF HALIDES

The figure shows the melting points of the chlorides of elements of the first four main groups. Those chlorides having melting points lying above the upper horizontal line behave like typical electrovalent compounds, being good conductors both in the fused state and in solution. Beryllium and aluminum chlorides are poor conductors in the fused state but conduct well in solution, indicating the tendency for polar covalent molecules to pass over into the electrovalent state in solution.

The remaining chlorides are typically covalent compounds having no conductivity in the liquid state (except lead chloride, which shows a slight conductivity). The chlorides of the group four elements should have symmetrical molecules and zero dipole

moments, thus accounting for their very low melting points. It seems likely that boron trichloride also has a symmetrical molecule. However, the tetrachlorides of both lead and tin conduct in solution indicating a tendency, as in the case of aluminum, to pass over into the electrovalent state.

We must consider at least one more class of solids before concluding. The properties of such compounds as boron nitride, aluminum carbide, silicon carbide, zinc sulfide, and many others of similar type, indicate that the molecules should have covalent links, yet such compounds have extremely high melting points, much higher than those of salts in most cases. The crystal lattices of such compounds are somewhat similar to those of salts except that the coördination numbers (the number of one species of atom located around the other) are lower, being in most instances 4. *The atoms, not molecules,* occupy points in the crystal lattice. No definite atomic groupings into distinct molecules is evident. Instead, covalent links extend in all directions throughout the crystal, much as electrovalent links extend throughout the salt crystal. The result is that the entire crystal is a "giant" covalent molecule, the stoichiometric relations being those found in the simple hypothetical molecules such as AlN, Al_4C_3, etc. Figure 11 illustrates the situation existing in such a molecule as SiC. Obviously, the "melting" of such a

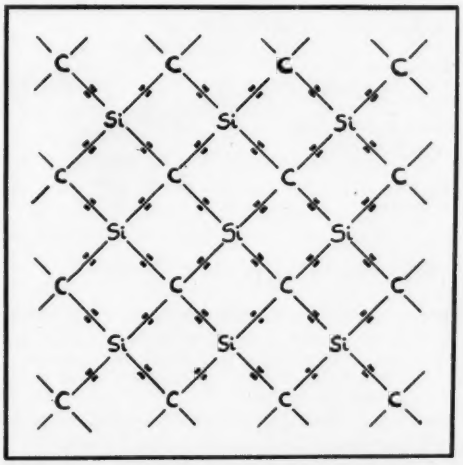


FIGURE 11.—COVALENT GIANT MOLECULE (SiC)

"molecule" means its decomposition, for the intra-atomic links must be broken. This is not a case of pulling molecules apart but of pulling covalently linked atoms apart. The energy required is much greater than that required to separate the ions in an electrovalent giant "molecule." The separation of the atoms produces not a liquid, but a gas. In other words, the compound sublimes.

Since the covalent link is a rigid one as well as a strong one, compounds of this type are extremely hard as well as non-volatile. The diamond is the best example of such an oriented giant molecule in which the most perfect conditions for the sharing of eight electrons among small and similar atoms are found. Giant molecules are very common among binary compounds of elements of groups III, IV, and V, less common in groups II and VI, and uncommon in groups I and VII. For a more complete discussion of the relation of valence to crystal structure the reader should consult the articles by Stillwell (7) in THIS JOURNAL. Figure 12 shows relative melting points.

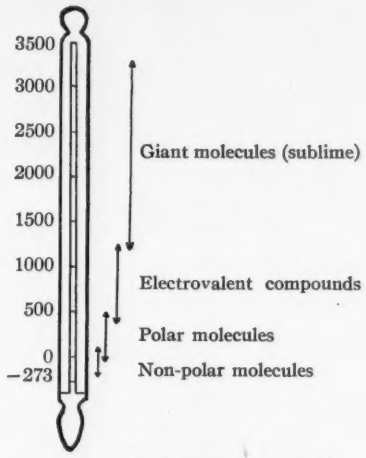


FIGURE 12.—MELTING RANGES

SUMMARY

In summarizing the applications of the concept of dipole moments to the phenomena of elementary chemistry, we may say that:

1. Coördination compounds are formed between molecules having high dipole moments, and proper donor and acceptor properties; between dipoles and ions, particularly between positive ions, water, and ammonia.
2. Liquids having high dipole moments are generally associated and have high boiling points while non-polar liquids have low boiling points which, in general, increase with increasing molecular weights.
3. Liquids of high dipole moment are excellent solvents for ions, good solvents for polar covalent compounds, and poor solvents for compounds of zero dipole moment. Non-polar liquids are mutually soluble when the zero moment is not the resultant of widely separated high moments.
4. The melting ranges of solids increase as the forces between the units increase in the following order:
   (*a*) van der Waals force between ideal non-polar molecules;
   (*b*) van der Waals force and residual electrostatic force between covalent molecules having high dipole moments.

(*c*) Electrostatic force between ions.
(*d*) Covalences in giant molecules (sublimation).

It seems by no means necessary or even advisable to present all of the material included in this article to a student of elementary chemistry. He need only be aware of the nature and general properties of polar molecules in order to use the concept in his reasoning on problems of coördination compounds, association, solubility, volatility, and solid structure. The better student might profit by considering more of the original evidence, methods, results, and difficulties.

Elementary chemistry of the future must become more and more a matter of reasoning and rationalization in general principles and less and less a study of multitudinous sets of specific properties, processes, and reactions. Advances made in the last quarter of a century in such topics as atomic structure, molecular structure, ionization, valence, and crystal structure have correlated much of our previously scattered and apparently unrelated information and have emphasized anew the importance of general principles. The new field of polar molecules regiments many more facts into organized bodies of knowledge capable of general interpretation and adds one more link to the important chain of chemical principles.

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COLLEGE ENTRANCE EXAMINATION BOARD

The Committee of Review of the College Entrance Examination Board at its meeting on Tuesday, October 29th, considered the report of the Commission on Examinations in Science. Professor Hugh S. Taylor, Chairman of the Commission, was present at the invitation of the Committee.

The Secretary stated that the report of the Commission had been printed and widely distributed with a request for criticism and suggestions. Copies of all the criticisms addressed to the Secretary had been transmitted to Professor Taylor and the other members of the Commission.

Professor Taylor reported that many of the points raised in the letters of criticism had previously been considered by the Commission. From the responses he inferred that the schools on the whole were in favor of the suggested increase in the range of the examinations and would welcome the proposed examinations. He said that most of those opposed to the proposed examinations at the third level were not aware of what had been done at certain secondary schools.

He admitted, however, that he did not think that the examinations at the third level were entirely practicable at the present time. The Commission, he said, had suggested such examinations for the purpose of encouraging the schools which are now giving three-year courses in science and in order to present an objective toward which science teaching should progress.

In response to an inquiry, Professor Taylor explained that the recommendations of the Commission would not in any way change the examinations now held in physics, chemistry, and biology. These are listed in the Commission's report as examinations at the first level.

On motion the Committee of Review voted to recommend to the Board the adoption of the following resolutions:

RESOLVED: That beginning in June, 1937, examinations in botany, zoölogy, physical geography, and mechanical drawing be discontinued.

RESOLVED: That during the next few years the Board make an intensive study of the effectiveness of examination procedures in biology, chemistry, and physics.

RESOLVED: That in June, 1937, the Board offer two new examinations, one in the field of the physical sciences including physics and chemistry and the other in the field of the biological sciences.

RESOLVED: That, as soon as expedient, examinations in biology, chemistry, and physics be offered by the Board for those students who have passed beyond the second level and who are simultaneously offering four-year or Gamma mathematics as a part of their examination program.

These resolutions were adopted by the College Entrance Examination Board at its meeting on Wednesday, October 30th.

METALLIC PROTACTINIUM

The accompanying photomicrographs, although not particularly spectacular in appearance, have historical significance in that they represent one of the first specimens of metallic protactinium ever produced. The preparation was made by A. V. Grosse, of The University of Chicago, and his assistants [see *J. Am. Chem. Soc.*, **56,** 220 (Oct., 1934)] by a method first introduced by Langmuir [*ibid.*, **37,** 1139 (1915)]. The pentachloride was decomposed in a high vacuum on the surface of an electrically heated tungsten filament.

Magnifications are about 40× and 100×, respectively. (*Photographs by W. Borst.*)

Courtesy of A. V. Grosse

LABORATORY THERMOREGULATOR

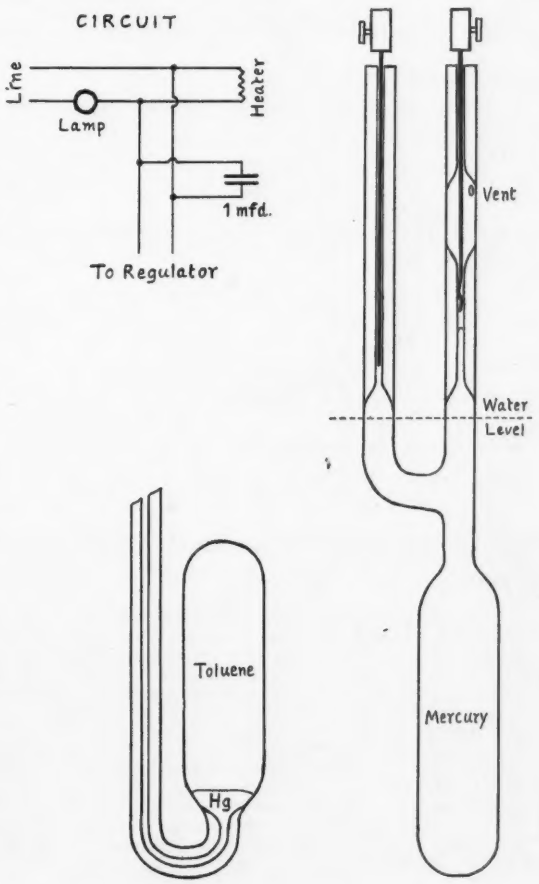
JOHANNES S. BUCK

The Burroughs Wellcome and Company, U. S. A., Experimental Research Laboratories, Tuckahoe, N. Y.

A VERY simple thermoregulator, suitable for maintaining a medium-sized thermostat at a moderate temperature above the surroundings, may be constructed by applying the idea of shorting out the heating element by the expansion of the thermoregulator fluid. This avoids the difficulties encountered when contact is made by the contraction of the fluid.

The apparatus is used directly on a 110-v. A.C. line, without resistances or relays. The glass part is readily constructed from pyrex glass tubing, 8 mm. O.D., and pyrex capillary, 8 mm. O.D. and 0.8 mm. I.D. The bulb is made from pyrex tube 25 mm. O.D. or larger. Mercury is used as the fluid, but toluene may be used in an inverted bulb. The external lamp serves as resistance. The heater in the bath may also be a lamp. The sizes of the lamps may be varied according to requirements. In a specific case, a 60-w. lamp in the bath, and a 100-w. lamp outside, kept 40 liters of water, in an uninsulated thin glass tank, at 25°C. Of course, some form of stirring device must be used in the tank.

The setting of the regulator is effected by adding mercury through the side-arm and by moving the contact wires. The latter are then fixed by melting a little sealing wax into the tops of the capillaries. Adjustment is not lost by allowing the bath to become cold. Resetting, if necessary, is accomplished by adjusting the contact wires, the sealing wax being softened by gentle flaming. No trouble is experienced through arcing if the contact wire (Chromel, 18 S.W.G.) be carefully filed to a blunt point and centered by giving it a slight spiral kink.



ELEMENTS *of the* QUANTUM THEORY*

IX. THE HELIUM ATOM. PART I. THE PERTURBATION METHOD

SAUL DUSHMAN

Research Laboratory, The General Electric Co., Schenectady, New York

1. FORMULATION OF THE PROBLEM

IN DEALING with the problem of the helium atom and atomic systems in general, it is convenient to use a system of so-called atomic units.† The advantage of this system may be illustrated by means of the S. equation for the hydrogen-like atom, which as stated in Chapter VI is of the form

$$\nabla^2\phi + \frac{8\pi^2\mu}{h^2}\left(E + \frac{Ze^2}{r}\right)\phi = 0 \qquad (208)$$

Let us choose as *unit of distance*, the radius of the equivalent Bohr orbit,

$$\alpha = \frac{a_0}{Z} = \frac{1}{Z}\cdot\frac{h^2}{4\pi^2\mu e^2} \qquad (322)$$

and as a *unit of energy*, the ionization-energy, that is,

$$-E = W = \frac{2\pi^2\mu e^4 Z^2}{h^2} = \frac{Ze^2}{2\alpha} = RchZ^2 \qquad (323)$$

[see equations (206)].

As shown in Chapter VI, the solution of equation (208) is of the form

$$\begin{aligned}\phi(r,\theta,\eta) &= S(r)\cdot Y(\theta,\eta)\\ &= S(r)\cdot P_l^m(\cos\theta)\cdot\epsilon^{im\eta}\end{aligned} \qquad (324)$$

where $S(r)$ is obtained as a solution of the radial equation,

$$\frac{d^2S}{dr^2} + \frac{2}{r}\cdot\frac{dS}{dr} + \left\{A + \frac{2B}{r} - \frac{l(l+1)}{r^2}\right\}S = 0 \qquad (212)$$

and

$$\begin{aligned}A &= 8\pi^2\mu E/h^2\\ B &= 4\pi^2\mu Ze^2/h^2\end{aligned} \qquad (213)$$

Let $r = \alpha\rho$. Then evidently

$$\frac{dS}{dr} = \frac{1}{\alpha}\cdot\frac{dS}{d\rho}, \quad \text{and} \quad \frac{d^2S}{dr^2} = \frac{1}{\alpha^2}\cdot\frac{d^2S}{d\rho^2}$$

Also from equations (322) and (323) it follows that

$$A = -1/\alpha^2$$

and

$$2B/r = 2/(\alpha^2\rho)$$

For the *normal state* of the hydrogen-like atom, $l = 0$. Hence, for this state equation (212) becomes

$$\frac{d^2S}{d\rho^2} + \frac{2}{\rho}\cdot\frac{dS}{d\rho} - \left(1 - \frac{2}{\rho}\right)S = 0 \qquad (325a)$$

which has the solution

$$S = -\epsilon^{-\rho}$$

as may readily be shown by differentiation of this function.

Also for this state, $Y(\theta,\eta) = 1$ and hence the complete eigenfunction is

$$\phi_{100}(\rho) = -\frac{\epsilon^{-\rho}}{\sqrt{N}}$$

corresponding to the form in which (325a) may be written,

$$\nabla^2\phi_{100} - \left(1 - \frac{2}{\rho}\right)\phi_{100} = 0 \qquad (325b)$$

The value of the normalizing factor, $\sqrt{N}$ is obtained from the relation

$$\int_0^\infty \phi_{100}^2 4\pi\rho^2 d\rho = \int_0^\infty \epsilon^{-2\rho}\cdot 4\pi\rho^2 d\rho = N$$

but

$$\int_0^\infty \epsilon^{-2\rho}\cdot 4\rho^2\cdot d\rho = 1$$

Hence

$$\sqrt{N} = \sqrt{\pi}$$

and

$$\phi_{100} = \phi_1 = -\frac{1\cdot\epsilon^{-\rho}}{\sqrt{\pi}} \qquad (326)$$

In terms of these units, the S. equation for the helium atom assumes the form

$$\nabla_1^2\phi + \nabla_2^2\phi + \left(\lambda + \frac{2}{\rho_1} + \frac{2}{\rho_2} - \frac{2}{Z\rho_{12}}\right)\phi = 0 \qquad (327)$$

where ρ_{12} denotes the distance between the two electrons.

For $1/Z = 0$, that is, for infinitely large nuclear charge, the solution is evidently given by the product of two eigenfunctions, each of which corresponds to one of the electrons in a quantum state defined by the numbers n, l, m, in the field of a nuclear charge, Ze.

Thus if electron 1 is in the state $n_1l_1m_1$ and electron 2 in the state $n_2l_2m_2$, the "zero-order" eigenfunction for the system is

$$\phi_{n_1n_2} = \bar{\phi}_{n_1}(\rho_1)\cdot\phi_{n_2}(\rho_2) \qquad (328)$$

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* This is the eleventh of a series of articles presenting a more detailed and extended treatment of the subject matter covered in Dr. Dushman's contribution to the symposium on Modernizing the Course in General Chemistry conducted by the Division of Chemical Education at the eighty-eighth meeting of the American Chemical Society, Cleveland, Ohio, September 12, 1934. The author reserves the right to publication in book form.

† Such units were first suggested by D. R. HARTREE [*Proc. Cambridge Phil. Soc.*, **24**, 89 (1926)] and have been adopted quite generally by writers on quantum mechanics. An interesting discussion of this topic is given by E. U. CONDON AND G. H. SHORTLEY in the Appendix of their recently published treatise, "The theory of atomic spectra," The Macmillan Company, New York, 1935.

where ρ_1 is an abbreviation for ρ_1,θ_1,η_1, and n_1 for $n_1l_1m_1$, with similar signification for ρ_2 and n_2. The total energy in the state n_1n_2 is given by

$$\lambda_0 = E_{n_1n_2} = E_{n_1} + E_{n_2} = -\left(\frac{1}{n_1^2}+\frac{1}{n_2^2}\right) \tag{329}$$

in terms of the units suggested already.

It is evident that the equation (329) will also represent the zero-order energy corresponding to the eigenfunction $\phi_{n_2n_1}$ in which the two electrons have interchanged quantum numbers. Thus we have here a *twofold degeneracy*, owing to the fact that the two states defined by $\phi_{n_1n_2}$ and $\phi_{n_2n_1}$ are indistinguishable when there is no interaction between the electrons. In the presence, however, of such a perturbing field we would expect to find that the degenerate state splits up into two states with energy-values which differ by an amount which *increases* with decrease in Z. That is, the effect due to electron interaction is greatest in the case of helium.

Only in the normal state ($n_1 = n_2 = 1$, $l_1 = l_2 = 0$, $m_1 = m_2 = 0$) is this degeneracy absent. We shall therefore consider first the solution of equation (327) for this state.

2. NORMAL STATE OF THE HELIUM ATOM

The zero-order eigenfunction for this state is

$$\psi_0 = \phi_1(\rho_1)\phi_1(\rho_2) = \frac{1}{\pi}\cdot\epsilon^{-(\rho_1+\rho_2)} \tag{330}$$

and the corresponding zero-order energy is evidently $\lambda_0 = -2$, that is, $E_0 = -2RchZ^2 = -8Rch$, where Rch is the ionization energy of a hydrogen atom in the normal state.

Applying the first-order perturbation theory, it follows from equation (292*b*), Chapter VIII, that the perturbation energy,

$$\Delta\lambda = \frac{2}{Z}\int\frac{1}{\rho_{12}}\cdot\phi_1^2(\rho_1)\phi_1^2(\rho_2)\cdot 4\pi\rho_1^2d\rho_1 4\pi\rho_2^2d\rho_2 \tag{331}$$

$$= \frac{32}{Z}\int\frac{\rho_1^2\rho_2^2}{\rho_{12}}\cdot\epsilon^{-2(\rho_1+\rho_2)}d\rho_1d\rho_2 \tag{332}$$

where the limits of integration for both ρ_1 and ρ_2 are 0 and ∞.

As shown in the following section, the value of the integral in (331) is (5/8), and consequently

$$\Delta\lambda = \frac{5}{4Z}$$

Hence

$$\Delta E = \frac{5}{4Z}\cdot RchZ^2 = \frac{5}{4}RchZ$$

and

$$E = E_0 + \Delta E = -2RchZ^2 + (5/4)RchZ$$

This gives the energy of the helium atom with respect to the *doubly ionized* atom, as represented by the process

$$He \longrightarrow He^{++} + 2e$$

On the other hand, the energy absorbed in the process,

$$He^+ \longrightarrow He^{++} + e$$

is $RchZ^2$.

Hence, the energy required for the process

$$He \longrightarrow He^+ + e,$$

that is, the ionization energy of the helium atom, is

$$V_i = Rch(Z^2 - (5/4)Z) = 13.56 \times 1.5 = 20.34 \text{ volts.}$$

Since the observed value is 24.46 volts, there is a discrepancy of 4.12 volts, that is, of about 17% of the correct value. But it should be noted that without the correction term, $(5/4)Z$, the calculated value for V_i would have been $13.56 \times 4 = 54.2$ volts, so that the correction introduced by use of the first-order perturbation has reduced the calculated value from one which is more than twice the observed value to one which is 17% *lower* than that observed. By calculating the second- and higher-order terms of the perturbation energy, a much better approximation to the correct value could be obtained. However, by the application of the method of variation of parameters, it has been found possible to avoid the tedious calculations involved in the use of the perturbation theory method with more satisfactory results. We shall therefore discuss the principles of the variational method in the following chapter.

3. INTERACTION OF CHARGE DISTRIBUTIONS

In order to calculate the values of integrals such as the one given in equation (331) or (332), it is necessary to evaluate definite integrals of the type

$$J_n = \int_{x_1}^{x_2}\epsilon^{-x}x^n dx$$

where, in general, $x_1 = 0$ or x, and $x_2 = x$ or ∞.

Since

$$\frac{d}{dx}(\epsilon^{-x}\cdot x^n) = nx^{n-1}\epsilon^{-x} - x^n\epsilon^{-x}$$

we obtain the relation

$$\int_{x_1}^{x_2}x^n\epsilon^{-x}dx = n\int_{x_1}^{x_2}x^{n-1}\epsilon^{-x}dx - (\epsilon^{-x_2}x_2^n - \epsilon^{-x_1}x_1^n)$$

That is, the evaluation of J_n is reduced to that of J_{n-1}. Proceeding in this manner it is readily shown that

$$\int_x^\infty x^n\epsilon^{-x}dx = \epsilon^{-x}\left\{n! + \frac{n!}{1!}x + \frac{n!}{2!}x^2 + \ldots + \frac{n!}{k!}x^k + \ldots x^n\right\} \tag{333}$$

and therefore,

$$\int_0^\infty x^n\epsilon^{-x}\,dx = n! \tag{334}$$

Hence

$$\int_0^x\epsilon^{-x}dx = 1 - \epsilon^{-x}; \quad \int_x^\infty\epsilon^{-x}dx = \epsilon^{-x}$$

$$\int_0^x x\epsilon^{-x}dx = 1 - \epsilon^{-x} - x\epsilon^{-x}$$

$$\int_x^\infty x\epsilon^{-x}dx = \epsilon^{-x} + x\epsilon^{-x}$$

$$\int_x^\infty x^2\epsilon^{-x}dx = 2\epsilon^{-x} + 2x\epsilon^{-x} + x^2\epsilon^{-x}$$

$$\int_0^\infty x^2\epsilon^{-x}dx = 2$$

The integral in equation (331) represents, physically, *the energy of interaction of two charge distributions.* While it could be calculated by expressing ρ_{12} as a function of ρ_1, ρ_2, and θ (the angle between the two radii) by the relation

$$\rho_{12}^2 = \rho_1^2 + \rho_2^2 - 2\rho_1\rho_2\cos\theta,$$

and then eliminating θ by an integration with respect to this variable, a much simpler method is available, which involves the application of potential theory.*

Let us consider a spherically symmetrical charge distribution described by the function $f(\rho)$. The total charge contained in a spherical shell of thickness $d\rho$ at $\rho = \rho_s$ is, therefore, $f(\rho_s)\cdot 4\pi\rho_s^2 d\rho$, and the potential of this shell at any point is given by

$$(1/\rho)4\pi\rho_s^2 f(\rho_s)d\rho \quad \text{for} \quad \rho > \rho_s$$

and by

$$(1/\rho_s)4\pi\rho_s^2 f(\rho_s)d\rho = 4\pi\rho_s f(\rho_s)d\rho \quad \text{for} \quad \rho < \rho_s$$

Hence the potential at a point $\rho = \rho_s$, due to the total charge distribution represented by

$$f(\rho_1) = \phi^2(\rho_1) = (1/\pi)\epsilon^{-2\rho_1}$$

is given by

$$V(\rho_s) = 4\pi\left\{\frac{1}{\rho_s}\int_0^{\rho_s}\phi^2(\rho_1)\rho_1^2 d\rho_1 + \int_{\rho_s}^\infty \phi^2(\rho_1)\rho_1 d\rho_1\right\} \quad (335a)$$

$$= 4\left\{\frac{1}{\rho_s}\int_0^{\rho_s}\epsilon^{-2\rho_1}\rho_1^2 d\rho_1 + \int_{\rho_s}^\infty \epsilon^{-2\rho_1}\rho_1 d\rho_1\right\}$$

$$= \frac{1}{\rho_s}\{1 - \epsilon^{-2\rho_s}(1+\rho_s)\} \quad (335b\dagger)$$

It should be observed that by the transformation

$$\int \epsilon^{-m\rho}\rho^n d\rho = \frac{1}{m^{n+1}}\int \epsilon^{-m\rho}(m\rho)^n d(m\rho)$$

$$= \frac{1}{m^{n+1}}\int \epsilon^{-x}x^n dx$$

it is possible to reduce integrals such as those in (335*b*) to the form considered in equations (333) and (334).

Let us now consider the interaction energy of this charge distribution with another charge distribution defined by $\phi^2(\rho_2) = (1/\pi)\epsilon^{-2\rho_2}$. This may be derived from a summation of terms, each of which gives the interaction energy between the charge distribution $\phi^2(\rho_1)$ and the charge located in the shell of thickness $d\rho$ at $\rho = \rho_2$. It is seen that these terms are of the form,

$$dU = V(\rho_2)\cdot\phi^2(\rho_2)\cdot 4\pi\rho_2^2 d\rho_2$$

where ρ_2 takes the place of ρ_s in equation (335*b*).

Hence, the total interaction energy due to the two charge distributions is

$$U = \int_0^\infty V(\rho_2)\cdot\phi^2(\rho_2)\cdot 4\pi\rho_2^2 d\rho_2$$

$$= \int_0^\infty \epsilon^{-2\rho_2}\cdot 4\rho_2^2\left\{\frac{4}{\rho_2}\int_0^{\rho_2}\epsilon^{-2\rho_1}\rho_1^2 d\rho_1 + 4\int_{\rho_2}^\infty \epsilon^{-2\rho_1}\rho_1 d\rho_1\right\} d\rho_2$$

$$= \int_0^\infty \epsilon^{-2\rho}4\rho^2\left\{\frac{1}{\rho} - \epsilon^{-2\rho}\left(1+\frac{1}{\rho}\right)\right\} d\rho$$

$$= 4\left(\frac{1}{4} - \frac{1}{32} - \frac{1}{16}\right) = \frac{5}{8}$$

This is the value of the integral in equation (331). It also follows from this result that

$$\int_{\rho_1=0}^\infty\int_{\rho_2=0}^\infty \frac{\rho_1^2\rho_2^2}{\rho_{12}}\cdot\epsilon^{-2(\rho_1+\rho_2)}\cdot d\rho_1 d\rho_2 = \frac{5}{8}\left(\frac{1}{4}\right)^2 = \frac{5}{128} \quad (336)$$

Consequently, as stated already,

$$\Delta\lambda = \frac{5}{4Z} = \text{first-order perturbation energy term.}$$

4. EXCITED STATES OF THE HELIUM ATOM

Let us now consider the case in which one of the electrons is in the state $n = 1$, $l = 0$ (state 1), and the other is in the excited state $n = n$, $l = 0$ (state n). As pointed out previously we find that in this case it is possible to have two eigenfunctions corresponding to the same zero-order energy value. These may be described thus:

	Electron 1	*Electron 2*	*Eigenfunction*
State:	1	n	$F_{1n} = \phi_1(\rho_1)\phi_n(\rho_2)$
State:	n	1	$F_{n1} = \phi_n(\rho_1)\phi_1(\rho_2)$

The system is therefore *twofold degenerate* and we must apply the perturbation theory as developed in Chapter VIII for this case. Instead, however, of utilizing directly the results deduced there, it will undoubtedly prove of help to the reader for a proper understanding of the more general discussion given in that chapter, if we apply these arguments to the more specific problem under consideration.

Since the functions F_{1n} and F_{n1} are equally valid solutions of the S. equation for the system, any linear combination of these will also be a solution. We therefore put

$$F = aF_{1n} + bF_{n1} \quad (337)$$

and write for the solution of the perturbed system

$$\phi = F + \psi \quad (338)$$

and for the energy of the perturbed system,

* The reader will find an especially interesting discussion of this topic in the paper by A. UNSÖLD, *Ann. Physik*, **82**, 355 (1926–27).

† This equation is the same, except for the difference in units of length, as equation (9) of Unsöld's paper.

$$\lambda = \lambda_1 + \lambda_2 + \eta \tag{339}$$

Substituting these in the S. equation (327), we obtain the equation,

$$(\Delta_1^2 + \nabla_2^2)(F + \psi) + \left(\lambda_1 + \lambda_2 + \eta + \frac{2}{\rho_1} + \frac{2}{\rho_2} - \frac{2}{Z\rho_{12}}\right)(F + \psi) = 0 \tag{340}$$

Since F_{1n} and F_{n1} satisfy the S. equation for the unperturbed system,

$$(\nabla_1^2 + \nabla_2^2)F + \left(\lambda_1 + \lambda_2 + \frac{2}{\rho_1} + \frac{2}{\rho_2}\right)F = 0$$

Neglecting products of the second order, it follows that

$$\nabla^2\psi + \left(\lambda_1 + \lambda_2 + \eta + \frac{2}{\rho_1} + \frac{2}{\rho_2}\right)\psi = \left(\frac{2}{Z\rho_{12}} - \eta\right)F \tag{341}$$

This equation is non-homogeneous, and in order that it shall have a solution, it is necessary, as shown in the first-order perturbation theory for the non-degenerate case, that the right-hand side of (341) shall be *orthogonal to each of the solutions*, F_{1n} and F_{n1}, of the corresponding homogeneous equation. Hence, we obtain the *two relations*,

$$\int (s - \eta)F \cdot F_{1n} \cdot d\tau = 0 \tag{342}$$

and

$$\int (s - \eta)F \cdot F_{n1} \cdot d\tau = 0 \tag{343}$$

where the integration is carried out over the configuration space,

$$d\tau = 4\pi\rho_1^2 d\rho_1 \cdot 4\pi\rho_2^2 d\rho_2, \text{ and } s = \frac{2}{Z\rho_{12}}$$

Substituting from (337) it follows that

$$a\int (s - \eta)F_{1n}^2 d\tau + b\int (s - \eta)F_{1n} \cdot F_{n1} d\tau = 0 \tag{344}$$

and

$$a\int (s - \eta)F_{1n}F_{n1} d\tau + b\int (s - \eta)F_{n1}^2 d\tau = 0 \tag{345}$$

Let

$$H_{11} = \int sF_{1n}^2 d\tau = \frac{32\pi^2}{Z}\int \frac{1}{\rho_{12}}\phi_1^2(\rho_1)\phi_n^2(\rho_2)\rho_1^2\rho_2^2 d\rho_1 d\rho_2 \tag{346}$$

$$H_{22} = \int sF_{1n}^2 \, d\tau = \frac{32\pi^2}{Z}\int \frac{1}{\rho_{12}}\phi_n^2(\rho_1)\phi_1^2(\rho_2)\rho_1^2\rho_2^2 d\rho_1 d\rho_2$$

$$H_{12} = H_{21} = \int sF_{n1}F_{1n} d\tau$$

$$= \frac{32\pi^2}{Z}\int \frac{1}{\rho_{12}}\phi_1(\rho_1)\phi_n(\rho_1)\phi_1(\rho_2)\phi_n(\rho_2)\rho_1^2\rho_2^2 d\rho_1 d\rho_2 \tag{347}$$

Now it is evident that

$$\int F_{n1}F_{1n} d\tau = \int \phi_1(\rho_1)\phi_n(\rho_1)4\pi\rho_1^2 d\rho_1 \int \phi_1(\rho_2)\phi_n(\rho_2)4\pi\rho_2^2 d\rho_2 = 0$$

Also that

$$\int F_{n1}^2 d\tau = \int \phi_n^2(\rho_1)\phi_1^2(\rho_2)4\pi\rho_1^2 \cdot 4\pi\rho_2^2 d\rho_1 d\rho_2 = \int F_{1n}^2 d\tau = 1$$

Furthermore, since the perturbation function $1/\rho_{12}$ is symmetrical with respect to ρ_1 and ρ_2,

$$H_{11} = H_{22}$$

Hence it follows that we can write equations (344) and (345) in the form

$$a(H_{11} - \eta) + bH_{12} = 0$$

and

$$aH_{12} + b(H_{11} - \eta) = 0$$

The solution of this pair of equations is given by the determinantal equation

$$\begin{vmatrix} H_{11} - \eta, & H_{12} \\ H_{12}, & H_{11} - \eta \end{vmatrix} = 0 \tag{348}$$

that is, $(H_{11} - \eta)^2 - (H_{12})^2 = 0$.

Equation (348) is usually designated a *secular equation*, which in the present instance is of the *second order*.

It follows that

$$\eta = H_{11} \pm H_{12}$$

and

$$a = \pm b.$$

Therefore, the two zero-order eigenfunctions are

$$F_S = a(F_{1n} + F_{n1})$$

and

$$F_A = a(F_{1n} - F_{n1})$$

where F_S is evidently a *symmetrical* function, since it does not change sign when the coördinates of the two electrons are interchanged, while F_A is *antisymmetrical*.

Since F_S and F_A must each be normalized, it follows that

$$1 = a^2\int (F_{1n}^2 + F_{n1}^2)d\tau \pm 2a^2\int F_{1n}F_{n1}d\tau$$

where the last integral on the right-hand side is equal to zero.

Therefore, $2a^2 = 1$; $a = 1/\sqrt{2}$, and the two zero-order eigenfunctions are

$$F_S = \frac{1}{\sqrt{2}}\{\phi_1(\rho_1)\phi_n(\rho_2) + \phi_n(\rho_1)\phi_1(\rho_2)\} \tag{349a}$$

and

$$F_A = \frac{1}{\sqrt{2}}\{\phi_1(\rho_1)\phi_n(\rho_2) - \phi_n(\rho_1)\phi_1(\rho_2)\} \tag{349b}$$

The corresponding eigenvalues to a first-order approximation are given by

$$\lambda_S = -\left(1 + \frac{1}{n^2}\right) + H_{11} + H_{12} \tag{350}$$

$$\lambda_A = -\left(1 + \frac{1}{n^2}\right) + H_{11} - H_{12} \tag{351}$$

where λ_S and λ_A are each expressed in units of $RchZ^2$.

The last two relations signify that as a result of the interaction of the electrons that state, for which the energy is $-(1 + 1/n^2)RchZ^2$ in absence of such interaction, is split up into *two states* which differ in energy value.

For the case $n = 2$, as shown in the next section,

$$RchZ^2 \cdot H_{11} = 0.420RchZ$$
$$RchZ^2 \cdot H_{12} = 0.044RchZ$$

so that

$$E_S = -(1 + 1/4)RchZ^2 + 0.464RchZ$$

and

$$E_A = -(1 + 1/4)RchZ^2 + 0.376RchZ$$

Thus E_A and E_S represent spectral energy levels which are symmetrically located with respect to the energy value $E = -(1 + {}^1/_4)RchZ^2 + 0.420RchZ$, and the *level corresponding to the antisymmetric state is lower*, since it is more negative. That is, the binding of the two electrons to the nucleus is greater for the antisymmetric state. If no repulsive forces existed between the electrons, the binding energy to the nucleus would be $(5/4)RchZ^2$. The existence of repulsive forces decreases this energy by $0.420RchZ$, corresponding to the term H_{11}. While the existence of this matrix element is therefore readily interpreted on the basis of classical concepts of interaction of electrical charge distributions, the existence of the additional term, $\pm H_{12}$ in the expression for the energy, results, as is evident from the previous considerations, from the solution of the S. equation, and is therefore a *non-classical* deduction. That this result is a purely quantum mechanical conclusion is of extreme significance, as will be pointed out in another section. Since the occurrence of the term $\pm H_{12}$ is due to the fact that the electrons may interchange "orbits," integrals of this type, which occur frequently in quantum mechanics calculations, have been designated as "*exchange integrals*" in contradistinction to the "*Coulomb integrals*" of which the term H_{11} is a typical example.

CALCULATION OF MATRIX ELEMENTS H_{11} AND H_{12}

To determine the values of the matrix elements H_{11} and H_{12}, it is necessary to evaluate the integrals in equations (346) and (347) for specific values of n. As an illustration of such a calculation, we shall consider the case $n = 2$, $l = 0$, $m = 0$, that is, the state of the electron designated spectroscopically as $2S$. The hydrogen-like eigenfunction for this state is given, in accordance with equation (241) in Chapter VI, by the expression

$$\phi_{200} = \phi_2 = \frac{(\rho - 2)\cdot\epsilon^{-\rho/2}}{\sqrt{N}} \qquad (352)$$

where

$$N = \int_0^\infty (\rho - 2)^2 \cdot \epsilon^{-\rho} 4\pi\rho^2 d\rho$$

$$= 4\pi \int_0^\infty (\rho^4 - 4\rho^3 + 4\rho^2)\epsilon^{-\rho}\, d\rho$$

$$= 32\pi$$

Thus the problem of evaluating the integral H_{11} is similar to that of the integral in equation (332), and as in equation (336) we put

$$H_{11} = \frac{2}{Z}\int_{\rho_2=0}^\infty \phi_2^2(\rho_2) 4\pi\rho_2^2 \left\{ \frac{1}{\rho_2}\int_0^{\rho_2} \phi_1^2(\rho_1)\cdot 4\pi\rho_1^2 d\rho_1 + \int_{\rho_2}^\infty \phi_1^2(\rho_1) 4\pi\rho_1 d\rho_1 \right\} d\rho_2$$

$$= \frac{2}{Z}\int_0^\infty \frac{\epsilon^{-\rho}(\rho - 2)^2}{32\pi}\cdot\frac{1}{\rho}\{1 - \epsilon^{-2\rho}(1 + \rho)\} 4\pi\rho^2 d\rho$$

$$= \frac{1}{4Z}\int_0^\infty \{\epsilon^{-\rho}(\rho^3 - 4\rho^2 + 4\rho) - \epsilon^{-3\rho}(\rho^4 - 3\rho^3 + 4\rho)\} d\rho$$

$$= \frac{1}{Z}\left(\frac{1}{2} - \frac{13}{162}\right) = \frac{1}{Z}\left(\frac{1}{2} - 0.0802\right) \qquad (353)$$

By analogy with the expression given in the last equation for calculating the integral H_{11}, the integral H_{12} is expressed in the equivalent form

$$H_{12} = \frac{2}{Z}\int_{\rho_2=0}^\infty \phi_2(\rho_2)\phi_1(\rho_2)\cdot 4\pi\rho_2^2 \left\{ \frac{1}{\rho_2}\int_0^{\rho_2} \phi_2(\rho_1)\phi_1(\rho_1) 4\pi\rho^2 d\rho_1 + \int_{\rho_2}^\infty \phi_2(\rho_1)\phi_1(\rho_1) 4\pi\rho_1\rho d\rho_1 \right\} d\rho_2 \qquad 354)$$

That is, we replace $\phi_2^2(\rho_2)$ and $\phi_1^2(\rho_1)$ by "mixed" distributions $\phi_2(\rho_2)\phi_1(\rho_2)$ and $\phi_2(\rho_1)\phi_1(\rho_1)$, *as if each electron were continuously alternating between the two quantum states*, so that the effective charge distribution is a geometrical mean, as it were, of the two well-defined distributions. From this point of view the origin of the designation "exchange integral" is readily understood.

Substituting in the integral in (354) from equations (326) and (352), the result is*

$$H_{12} = \frac{2}{Z}\int_0^\infty \frac{\epsilon^{-(3/2)\rho_2}(\rho_2 - 2)}{4\pi\sqrt{2}}\cdot 4\pi\rho_2^2 \left\{ \frac{1}{\rho_2}\int_0^{\rho_2} \frac{\epsilon^{-(3/2)\rho_1}}{4\pi\sqrt{2}}(\rho_1 - 2)\cdot 4\pi\rho_1^2 d\rho_1 + \int_{\rho_2}^\infty \frac{\epsilon^{-(3/2)\rho_1}}{4\pi\sqrt{2}}(\rho_1 - 2)\cdot 4\pi\rho_1 d\rho_1 \right\} d\rho_2$$

$$= \frac{1}{Z}\cdot\frac{32}{3^6} = \frac{0.0439}{Z}$$

For the general case in which one electron is in the state $n = 1$, $l = 0$, and the other in the state $n > 1$, $l = 0$, the integrals H_{11} and H_{12} may be expressed, as shown by Unsöld, by the relations

$$H_{11} = \frac{1}{Z}\left(\frac{2}{n^2} - a\right) \qquad (355)$$

$$H_{12} = \frac{1}{Z}\cdot b \qquad (356)$$

in terms of $RchZ^2$ as a unit of energy. For different values of n, the constants a and b have the values indicated in the following table

n:	2	3	4
a:	0.0802	0.0232	0.00973
b:	0.0439	0.0115	.00468

The fact that a decreases with increase in n is due to the decrease in Coulomb energy of repulsion between the electrons. The electron wave functions "overlap" less as n is increased. The decrease in the exchange energy, H_{12}, with increase in n is accounted for on the same basis.

5. EXCHANGE ENERGY

As mentioned already, the existence of exchange energy terms, such as H_{12}, is a purely quantum effect

* A. UNSÖLD, *loc. cit.*

which has no classical mechanics analog. The nearest analog to the phenomenon is that of the interaction of linear harmonic oscillators, or that of the electron oscillating between two adjacent potential boxes. As pointed out in Chapter VII, each of the single energy levels which exist for the unperturbed states of the system (in absence of any coupling action) is split up, as a result of the interaction, into two levels. The difference in energy of any pair of such levels decreases with increase in n. Also corresponding to each of these pairs of levels there exist a symmetric and an antisymmetric eigenfunction.

Thus there is a certain resemblance between the effect which gives rise to the van der Waals energy of attraction and the interchange energy which occurs in the solution of the helium atom problem. It is, however, a purely formal analogy and cannot be used to give a physical interpretation of the results deduced in the present chapter.

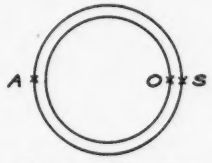

FIGURE 47.—SYMMETRY AND ANTISYMMETRY OF ELECTRONS*

*From "The New Conceptions of Matter," by C. G. Darwin.

The difference between the symmetric and antisymmetric states of the excited helium atom may be represented diagrammatically by Figure 47 which is taken from the excellent discussion of this topic by C. G. Darwin.†

The two electrons are assumed to be in "orbits" with angular momenta differing by one quantum ($n_1 = 1$, $n_2 = 2$). As Darwin points out, "If one electron is found to be at **O**, then in the symmetric mode the other is most likely to be at **S**, whereas in the antisymmetric mode it is most likely to be at **A**." From this point of view the fact that E_A is greater numerically than E_S is evidently due to the smaller magnitude of the repulsive energy term between the electrons when they are in the antisymmetric state, so that the net attractive energy between each electron and the nucleus is greater.

One important point that should be noted is that the energy term, H_{12}, *is not due to the action of some new force.* While the Coulomb integral, H_{11}, may be regarded as expressing the energy arising from the Coulomb forces of repulsion between the electrons, and the term $-RhZ^2\left(1 + \frac{1}{n^2}\right)$ is due to the Coulomb forces of attraction between each electron and the nucleus, the exchange energy has no such interpretation. As emphasized already it is due to the fact that the two electrons may interchange "orbits." This is expressed by the designation of the integral H_{12} as exchange or resonance energy (by analogy with the case of two coupled oscillators). It will be observed that the existence of the exchange energy term is bound up with the existence of a twofold degeneracy, as indicated in equation (347) by the relation,

$$H_{12} = H_{21} = \int\left(\frac{2}{Z\rho_{12}}\right) F_{1n}F_{n1}d\tau$$

† C. G. DARWIN, "The new conceptions of matter," p. 205.

Furthermore, in the case of the helium atom, this expression has a *positive value.* This result will appear of special significance in the discussion of the hydrogen molecule problem in a subsequent chapter.

Since, in classical mechanics, we define a force as the negative derivative of the energy with respect to distance, in accordance with the relation

$$F = -\partial E/\partial r$$

we could logically consider the exchange energy as due to "exchange forces." However, the form of the expression for H_{12} shows that such a calculation would not only be tedious, but also meaningless.

In fact, we find that in quantum mechanics, the concept "force" is not required. After all, the only magnitude susceptible of measurement is that of the energy involved in the formation of an atom from nucleus and electrons; or the energy of dissociation of a molecule. Even in the case of van der Waals' forces, which were discussed in Chapter VII, the quantum mechanics calculation led to a value for the interaction energy of the form

$$\Delta E = -\frac{3}{4}\cdot\frac{h\nu_0\alpha^2}{r^6}$$

From this it follows as a *mathematical consequence* that

$$\frac{-d(\Delta E)}{dr} \sim \frac{1}{r^7}$$

and if we wish to regard this as defining a force which is a function of r, it is permissible to do so. But actually this deduction does not in any manner help toward a better understanding of the phenomenon.

6. ORTHOHELIUM AND PARHELIUM

As shown in the previous section, quantum mechanics leads to the conclusion that the spectrum of helium should exhibit two sets of energy levels. In accordance with equations (350), (351), (355), and (356), these are defined, in the case $l = 0$ (s-levels) by the relations,

$$E_S = -\left(1 + \frac{1}{n^2}\right)RchZ^2 + \left(\frac{2}{n^2} - a\right)RchZ + bRchZ$$

$$E_A = -\left(1 + \frac{1}{n^2}\right)RchZ^2 + \left(\frac{2}{n^2} - a\right)RchZ - bRchZ$$

In terms of *wave-numbers* ($\tilde{\nu} = -E/(hc)$) these are given by

$$\tilde{\nu}_{S,A} = RZ^2\left(1 + \frac{1}{n^2}\right) - \frac{2RZ}{n^2} + RZ(a \mp b)$$

where $(a - b)$ refers to $\tilde{\nu}_S$ and $(a + b)$ to $\tilde{\nu}_A$, that is, for any given value of n the term with the smaller numerical value of $\tilde{\nu}$ should correspond to the symmetrical state.

Actually, the spectrum of helium (see Figure 48) shows two sets of energy levels which were at one time regarded as characteristic of two different atomic species. These are known as the *parhelium* and *orthohelium* series. Each level is designated by the quantum states of the two electrons. Thus, the lowest level is

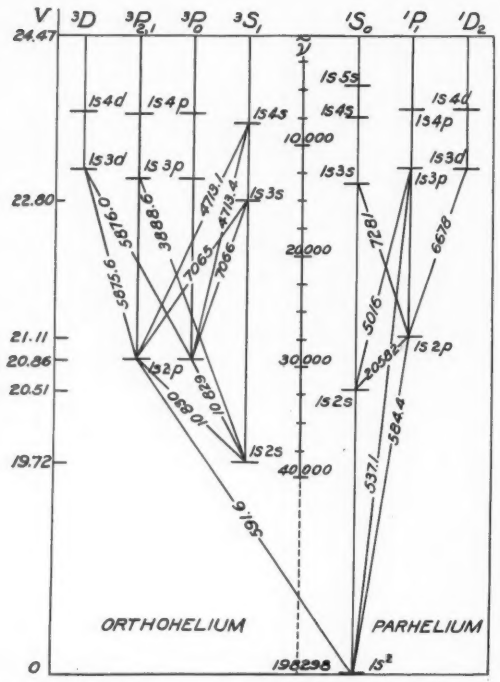

FIGURE 48.—ENERGY LEVELS IN SPECTRUM OF HELIUM

$1s^2$ which indicates that each electron is in the state $n = 1$, $l = 0$ (s-levels), while in the two next higher levels, one electron is in the state $1s$ and the other in the state $2s(n = 2, l = 0)$. It will be observed that for any given values of n, the level in the parhelium series has the numerically smaller value of the wave number. Consequently, the *parhelium terms must correspond to the symmetrical eigenfunctions* and the orthohelium terms to the antisymmetrical eigenfunctions.

The energy diagram also shows that the terms in the orthohelium series are actually triplets, whereas the corresponding terms in the parhelium series are singlets. Thus, there are three levels in the orthohelium series corresponding to the electron configuration $1s2p$ ($n = 1$, $l = 0$ for one electron, and $n = 2$, $l = 1$ for the other electron). Two of these levels (column designated $3P_{2,1}$) are so close that it is impossible to indicate them on the diagram as separate levels.

In order to interpret the existence of multiplet levels such as those which occur in the case of helium, it has been found necessary to introduce the concept of electron spin. Since this concept and the related generalization, known as Pauli's Exclusion Principle, are of fundamental importance in quantum mechanics, we shall consider these topics in the following section.

7. ELECTRON SPIN. PAULI'S EXCLUSION PRINCIPLE

As shown in Chapter VI, the solution of the S. equation for the hydrogen atom leads to a number of eigenfunctions which require for their designation the three quantum numbers, n, l (where $l = n - 1, n - 2, \ldots 0$) and m (where $m = \pm l, \pm(l - 1) \ldots 0$). Since all the eigenfunctions for any given value of n have the same eigenvalue,

$$E_n = -\frac{Z^2e^2}{2n^2a_0} \tag{235}$$

we designate this state as *degenerate*. It was also shown that the degree of degeneracy for a given value of n is n^2.

For any given values of l and m, the total angular momentum of the electron in its motion about the nucleus is given by

$$M = \sqrt{l(l+1)}\cdot(h/2\pi) \tag{247}$$

while the component of this momentum about the Z-axis is

$$M_Z = m(h/2\pi) \tag{248}$$

In the presence of perturbing fields, such as those produced by the presence of other electrons in the atomic system, or by magnetic or electrostatic fields, the degeneracy may be removed either partly or even completely. Thus in the case of all the atomic systems for which $Z > 1$, the degeneracy with respect to l is removed, so that the states corresponding to different values of l, for the same value of n, have energy values which are no longer identical. These states are designated spectroscopically by the symbols s (for $l = 0$), p (for $l = 1$), d (for $l = 2$), and so forth.

The observations on the effect of magnetic fields on spectral lines (Paschen-Back Effect) show that in a magnetic field the total number of states corresponding to a given value of l is not $2l + 1$ as expected from the previous considerations but *twice this number*. Thus the maximum number of levels for a $1s$, $2s$, or ns electron is 2, in spite of the fact that m can have only the single value 0. Similarly, for an np electron the maximum number of levels is $2(2 \times 1 + 1) = 6$, and for an nd electron, $2(2 \times 2 + 1) = 10$.

Formally, this may be accounted for, as first pointed out by Uhlenbeck and Goudsmit, by the assumption of a spinning electron. The magnitude of the *total* angular momentum of spin is $\sqrt{s(s+1)}\cdot h/(2\pi)$, where s designates the *electron spin quantum number*. The component of this momentum in any given direction is $m_s\cdot(h/2\pi)$, where m_s is a fourth quantum number, the value of which is either $+1/2$ or $-1/2$.

Thus any electron has assigned to it not only the three orbital quantum numbers n, l, m, but also a fourth number known as the magnetic quantum number, m_s $(= \pm 1/2)$ which defines the component of angular momentum with respect to a given axis.

By this theory it is possible to account not only for the observations on the effect of magnetic fields on spectral lines, but also for the existence of multiplet levels as deduced from the spectra of atomic systems containing more than one electron.*

* For the discussion of this important topic, the reader should consult the following treatises: (1) H. E. WHITE, "Introduction to atomic spectra," McGraw-Hill Book Company, New York, 1934; (2) L. A. PAULING AND S. GOUDSMIT, "The structure of line spectra," McGraw-Hill Book Company, New York, 1930.

For quantum mechanics the significance of these considerations is of importance because of Pauli's Exclusion Principle, which may be enunciated as follows:

In any one atom there cannot exist two electrons having the four quantum numbers (n, l, m, and m_s), respectively, the same in both.

Thus, if for two electrons, $n_1 = n_2$, $l_1 = l_2$, $m_1 = m_2$, then m_s cannot be identical for both, but must have the value $+1/2$ for one and $-1/2$ for the other electron. That is, two electrons which are identical with respect to each of the three "orbital" quantum numbers, must be anti-parallel with respect to the directions of the vectors which correspond to the spin momenta.

Pauli's principle is essentially the real justification for the scheme of electron distribution first suggested by E. C. Stoner and independently by J. D. Main-Smith in 1924. Assuming that the maximum number of electrons of any one type (s, p, d, etc.) which an atomic system may possess is given by the value of $2(2l + 1)$, it is possible to deduce the variation in electron distribution as electrons are added in succession to a nucleus of charge $+Ze$. On this basis an adequate interpretation has been obtained of the periodic arrangement of the elements and of the variation in the characteristics of their spectral terms.

8. MULTIPLET LEVELS IN SPECTRUM OF HELIUM

From Pauli's principle it follows that in the lowest electronic state (normal state) of the helium atom, in which both electrons are in $1s$ states, the spins must be in *opposite directions*. Since the normal state belongs to the parhelium series, this argument is additional confirmation of the conclusion, stated in a previous section, that the parhelium states correspond to the symmetrical eigenfunctions.

To account for the existence of multiplets it is necessary to introduce into the quantum mechanics formulation of the eigenfunctions the electron spin concept. The procedure used for this purpose is as follows:*

It is assumed that corresponding to the electron-spin there exists an eigenfunction $\psi(s)$ which designates the orientation of the axis of spin in a magnetic field.† For two electrons there will exist two such functions, $\psi(s_1)$ and $\psi(s_2)$, and consequently the *complete* spin function for such a system may be represented by any one of the combinations shown in the attached table. The first two columns give the values of m_s, the third that of Σm_s, and the last column the corresponding combination.

m_{s1}	m_{s2}	Σm_s	*Eigenfunction*
$1/2$	$1/2$	1	$\psi(1/2)\psi(1/2) = \alpha$
$1/2$	$-1/2$	0	$\psi(1/2)\psi(-1/2) = \beta$
$-1/2$	$1/2$	0	$\psi(-1/2)\psi(1/2) = \gamma$
$-1/2$	$-1/2$	-1	$\psi(-1/2)\psi(-1/2) = \delta$

* The following remarks are based upon the discussion in A. SOMMERFELD'S "Wave mechanics," pp. 231–3.

† The reader will find a somewhat different method of presentation of spin eigenfunctions in Pauling and Wilson's book, p. 210. For the purpose of the present discussion this elaboration is, however, not essential.

The eigenfunctions β and γ evidently represent a degenerate state, since they correspond to interchange of electrons, and we must therefore replace them for the perturbed state of the system by $(\beta + \gamma)/\sqrt{2}$ and $(\beta - \gamma)/\sqrt{2}$. The factor $1/\sqrt{2}$ is introduced for the same reason as it was introduced in equations (349a) and (349b) for the orbital eigenfunctions F_S and F_A. We thus obtain three spin eigenfunctions which are symmetrical in the electron spins, *viz.*:

$$\alpha,\ (\beta + \gamma)/\sqrt{2},\ \text{and}\ \delta$$

and one which is antisymmetrical, *viz.*: $(\beta - \gamma)/\sqrt{2}$. The first set give rise to triplet terms, for which the values of Σm_s are -1, 0, and 1, while the last function corresponds to the singlet term, $\Sigma m_s = 0$.

The *complete* eigenfunctions for the system of two electrons are obtained as the *products of orbital and spin functions*. According to equations (349a) and (349b), the orbital eigenfunctions are

$$F_S = \frac{1}{\sqrt{2}}(F_{1a} + F_{a1}) = u + v$$

and

$$F_A = \frac{1}{\sqrt{2}}(F_{1a} - F_{a1}) = u - v$$

Hence, we obtain the following eight combinations of orbital and spin functions which we shall arrange in two sets:

(A) $(u + v)\alpha;\ (u + v)(\beta + \gamma)/\sqrt{2};\ (u + v)\delta;\ (u - v)(\beta - \gamma)/\sqrt{2}$

(B) $(u + v)(\beta - \gamma)/\sqrt{2};\ (u - v)\alpha;\ (u - v)(\beta + \gamma)/\sqrt{2};\ (u - v)\delta$

Group (A) evidently contains only symmetrical functions, while group (B) consists of the antisymmetrical functions. Now in the energy-level diagram for helium we observe that corresponding to a given value of n and a value of $l > 0$ for the excited state of one of the electrons, there are only *four* levels, three of which belong to the triplet (orthohelium) series and the other to the singlet (parhelium) series. As deduced previously, the latter correspond to the functions which are symmetrical in the orbital functions and antisymmetrical in the spin functions. This evidently means that the parhelium series corresponds to the eigenfunction $(u + v)(\beta - \gamma)/2$ and that the orthohelium series corresponds to the other three members of group (B).

This conclusion may be stated in the following very significant generalization: *The complete solution of the wave equation for any atomic system must involve only that type of eigenfunction which is antisymmetrical*, that is, changes sign when the electrons are interchanged. Evidently, this is the quantum mechanics interpretation of Pauli's exclusion principle, and we shall find it extremely important in the consideration of valence problems.

One other deduction which should be mentioned in this connection is the following.

In absence of any interaction between the electron spins and the orbital motions, no transition can occur between a state corresponding to a symmetrical eigenfunction, F_S, and another state corresponding to an antisymmetrical function, F_A. As shown in the energy-level diagram, Figure 48, there is only one line (λ591.6), and that a faint one, which corresponds to a transition between the ortho- and parhelium series. On the other hand, with atoms of higher nuclear charge, where there is interaction between the electron spin and the orbital motion, lines corresponding to transitions between singlet and triplet levels frequently occur.

MATHEMATICAL PROBLEM PAGE

Directed by EDWARD L. HAENISCH

Montana State College, Bozeman, Montana

THE first-order, first-degree differential equation, $Mdx + Ndy = 0$, is exact if $\partial M/\partial y = \partial N/\partial x$ (*Euler's Criterion*). Integration of exact differential equations was discussed in the January Problem Page. An inexact differential can be made exact by multiplication of the equation by an integration factor. Thus, if $Mdx + Ndy = 0$ is inexact and μ is an integration factor, the equation, $\mu(Mdx + Ndy) = 0$ is exact. The number of such factors is infinite and special rules can be formulated for finding the factors for certain types of functions. In many cases the factor can be found by inspection.

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PROBLEMS

1. Find several integrating factors for $ydx - xdy = 0$ and show that the solutions obtained by the use of these factors are equivalent.

2. Solve: $ax^2y^n(dy/dx) = 2x(dy/dx) - y$. (Hint: Use the integration factor, y/x^2. The equation will be divided into a term in y alone and an exact differential.)

3. Solve: $x(x^2 + 3y^2)dx + y(y^2 + 3x^2)dy = 0$
$(1 + xy)ydx + (1 - xy)xdy = 0$
$(y - x)dy + ydx = 0$
$y(2xy + e^x)dx - e^xdy = 0$

4. Show that e^{-ax} is an integration factor for $dy + aydx = Qdx$ where a is a constant and Q is a function of x alone. Obtain the solution of the equation.

SOLUTIONS TO FEBRUARY PROBLEMS

1. $y = ax^2 + bx$ (A)
$dy/dx = 2ax + b$ (B)
$d^2y/dx^2 = 2a$ (C)
Multiply (B) by x and subtract from (A)
$y - x(dy/dx) = -ax^2$
Substitute the value of a from (C)

$$y - x\frac{dy}{dx} + \frac{1}{2}\left(\frac{d^2y}{dx^2}\right)x^2 = 0$$

2. $yxdx + xy^2dy = 0$
Division by xy will separate the variables.
$dx + (dy/y) = 0$; $x + \ln y = C$
Rearranging: $\ln y - \ln C = -x$; or $y = Ce^{-x}$
Factoring the equation: $x^2(1 - y)dy + y^2(1 + x)dx = 0$
Division by x^2y^2 will separate the variables.

$$\frac{1 - y}{y^2}dy + \frac{1 + x}{x^2}dx = 0$$

$$-\frac{1}{y} - \ln y - \frac{1}{x} + \ln x = C$$

For convenience C may be written as $\ln C$

$$\ln\frac{x}{y} = \ln C + \frac{1}{x} + \frac{1}{y}$$

$$x = Cye^{\left(\frac{1}{x} + \frac{1}{y}\right)}$$

3. The substitution $y = vx$ and $dy = xdv + vdx$ gives:
$vx^3dx - (x^3 + v^3x^3)(xdv + vdx) = 0$
$vdx - (1 + v^3)(xdv + vdx) = 0$
$vdx - (xdv + vdx + xv^3dv + v^4dx) = 0$
$-xdv - xv^3dv - v^4dx = 0$
$x(1 + v^3)dv + v^4dx = 0$
This is solvable by separation of the variables.

$$\frac{dx}{x} + \frac{1 + v^3}{v^4}dv = 0$$

$$-\frac{1}{3}v^{-3} + \ln x + \ln v = \ln C$$

$$vx = Ce^{1/3v^3}$$

Substituting for v we obtain: $y = Ce^{x^3/3y^3}$

4. $$\frac{dy}{dx} = \frac{7x - 3y - 7}{7y - 3x + 3}$$

Substitute $x = u + h$, $dx = du$, $y = v + k$ and $dy = dv$.

$$\frac{dv}{du} = \frac{7u + 7h - 3v - 3k - 7}{7v + 7k - 3u - 3h + 3}$$

h and k are chosen so that:
$7h - 3k - 7 = 0$
$-3h + 7k + 3 = 0$
whence $k = 0$ and $h = 1$.

$$\frac{dv}{du} = \frac{7u - 3v}{7v - 3u}$$

This equation is homogeneous and can be solved by the substitution $v = nu$, whence the equation reduces to:
$7udu = (n^2 - 1) + u^2(7n - 3)dn = 0.$

$$7\frac{du}{u} + 7\frac{ndn}{n^2 - 1} - 3\frac{dn}{n^2 - 1} = 0$$

$$7 \ln u + \frac{7}{2}\ln (n^2 - 1) - \frac{3}{2}\ln\frac{n - 1}{n + 1} = \ln C$$

Replacing u by $x - 1$, v by y, and n by $y/(x - 1)$ we obtain:

$$7 \ln (x - 1) + \frac{7}{2}\ln\left(\frac{y^2}{(x - 1)^2} - 1\right) - \frac{3}{2}\ln\frac{y - x + 1}{y + x - 1} = \ln C$$

which reduces by algebraic manipulation to:

$$(y - x + 1)^2(y + x - 1)^5 = C$$

5. $pdV = -c_v dT$

Substitute RT/V for p and separate the variables:

$$\frac{R}{c_v}\frac{dV}{V} = -\frac{dT}{T}$$

$$\frac{R}{c_v}\ln V + \ln T = \ln C$$

$$V^{\frac{R}{c_v}} T = C$$

Substitute $c_p - c_v$ for R and recall that $\gamma = c_p/c_v$

$$V^{\gamma - 1}T = C$$

Substituting pV/R for T we obtain pV^γ = constant.

6. $$\frac{dx}{(a - x)(b - x)} = kdt$$

Using the method of partial fractions we have:

$$\frac{1}{(a - x)(b - x)} = \frac{A}{a - x} + \frac{B}{b - x}$$

$$\frac{1}{(a - x)(b - x)} = \frac{A(b - x) + B(a - x)}{(a - x)(b - x)}$$

$$A(b - x) + B(a - x) = 1$$

This is an identity which must be true for any value of x.
If $x = a$, $A(b - a) = 1$ and $A = 1/(b - a) = -1/(a - b)$
If $x = b$, $B(a - b) = 1$ and $B = 1/(a - b)$

$$\frac{dx}{(a - x)(b - x)} = \frac{1}{a - b}\left(\frac{dx}{b - x} - \frac{dx}{a - x}\right) = kdt$$

$$\frac{1}{a - b}\ln\frac{a - x}{b - x} = kt + C$$

When $t = 0$, $x = 0$ and $C = \frac{1}{a - b}\ln\frac{a}{b}$.

$$k = \frac{1}{t}\cdot\frac{1}{a - b}\ln\frac{b(a - x)}{a(b - x)}$$

CORRESPONDENCE

SOME COMPONENT ERRORS IN DETERMINING THE VOLUME OF A MOL OF OXYGEN

To the Editor

DEAR SIR:

An error in substitution occurred in the article entitled "Some Component Errors in Determining the Volume of a Mol of Oxygen" which was printed in the January issue of the JOURNAL. On page 39 near the end of the last column the final derivation should be $\Delta v = \pm \frac{v\Delta w \times 0.46}{w}$. The error in volume Δv then becomes $\Delta v = \pm \frac{1196 \times 0.0069 \times 0.46}{1.7106}$ and $\Delta v = \pm 2.22$ ml. The table at the end of page 40 which concludes the article should be revised as follows:

P.E. of weight of oxygen	*Error in volume which is insignificant at S.T.P.*
±0.005 g.	±1.03 ml.
0.007	2.25
0.009	2.9
0.01	3.22

CHARLES F. ECKELS

PASADENA JUNIOR COLLEGE
PASADENA, CALIFORNIA

To the Editor

DEAR SIR:

I would like to call attention to an error in the article, "Some Component Errors in Determining the Volume of a Mol of Oxygen," which appears in the January, 1936, issue of the JOURNAL OF CHEMICAL EDUCATION. The expression $0.46E = e$ I believe should read $E = 0.46\,e$. The result is that the value for the "largest error allowable in measuring v" is four times too large.

I agree with Mr. Eckels that a freshman chemistry student should know enough about the elements of precision to be able to determine whether a meter stick or micrometer calipers should be selected as the correct tool to measure a length. However, I do not agree that the elaborate and accurate mathematical development suggested by him should be used to teach these "elements of precision" to freshman students. My experience has been that such mathematical elaboration only serves to confuse the ordinary student. Even when the method and form of calculation has been mastered the true significance of the calculations and the existing relationships are rarely understood. Upperclass students who have been exposed to the elaborate mathematical development during their freshman or sophomore years may be able to calculate the "probable error" but more often than not they have no idea of how many significant figures should be used in expressing the result of a simple multiplication or division of measured quantities. They "cannot see the woods for the trees."

In the short time that one has available for the intro-

duction of the elements of precision in a first-year course in chemistry one can hardly do more than point out the significance of precision in obtaining measured quantities, the meaning of "significant figures" and "percentage precision" and the application of these relatively simple concepts to operations of measurement, multiplication, and division. Even these are difficult enough for first-year college students. Only a small percentage of them understand the principles well enough to continue to apply them intelligently in their experimental work and in the solution of problems.

WALTER R. CARMODY

REED COLLEGE
PORTLAND, OREGON

"INTRODUCTION TO INORGANIC CHEMISTRY"

To the Editor

DEAR SIR:

In the December, 1935, number of the JOURNAL OF CHEMICAL EDUCATION on p. 599 is published my review of G. H. Cartledge's new book "Introduction to Inorganic Chemistry." My attention has been called to an incorrect statement which is made in this review. At the top of the second column occurs the statement "Acids, bases, and salts are developed by the Arrhenius theory, with no mention of other viewpoints." These last six words are obviously in error, since the Brönsted conception is explained in a very satisfactory manner, referred to frequently, and used throughout the later pages of the book.

I am extremely sorry for this misstatement and I wish you would be kind enough to publish this correction in a prominent position in order to undo as completely as possible any possible harm which may have resulted from this unfortunate expression.

B. S. HOPKINS

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

PROSPECTIVE TEACHER SELECTION

To the Editor

DEAR SIR:

I have read with a great deal of interest your editorial in the JOURNAL for January on "Preferred Risks in Teaching." I do not wonder at all that you accept as true the general theme, supported by distinguished authority, that "students who enter normal schools and teachers' colleges and who elect preparatory curricula in other types of institutions are, as a group, inferior in ability and personality to those who select other professions and lines of work." And I think that you are very nearly, if not absolutely, right in accepting as true Dean Sangren's statement, as follows: "When high school counselors and teachers, themselves, have sufficient personal interest in and respect for their own profession, more desirable candidates will be directed into the field," although this statement fails to mention the persuasion (almost coercion) exercised by many high-school principals in recruiting their most promising students for entrance into a college or colleges in which the principal has an interest, usually as an alumnus. With your general observations I have no quarrel, but I feel constrained to utter a protest so far as Rhode Island College of Education may be concerned.

In the first instance, ten years ago the State Department of Education in Rhode Island gave serious consideration to the problem of teacher supply and demand. Careful statistical studies of the number of teachers needed annually for new positions and replacements were made. The Department accepted as a principle of efficiency and justice that the State should not train more teachers than were needed. So far as the State was concerned, the application of justice affected the taxpayers, who should not be asked to pay for the education of persons who could not find places in the public schools. The principle of justice affected prospective students as well; no young person should be accepted as a cadet or apprentice if there were not to be, at the conclusion of the training period, reasonable expectation of placing him in a teaching position. Hence the State Department limited the size of entering classes to the average number of positions to be filled annually.

Immediately, a question arose as to selection for admission, and a competitive examination was inaugurated. In succeeding years, as the number of applicants has increased, the process of elimination has become more and more drastic. In recent years, 60 per cent. of applications have been rejected, and 40 per cent. accepted. Thus the student admitted to Rhode Island College of Education, so far as his academic standing may be ascertained by examination, is a member of the upper two-fifths of his class. Additional to the examination, careful estimates of the applicant's record in high school or secondary school is made, a particular report on "personality" is required from his principal or teachers, and a rigid physical examination is made by a medical doctor. As a by-product of the sifting process it has come to be true that admission to the College of Education is esteemed as an honor to be striven for, and many superintendents and principals take pride in nominating candidates for the examinations, and are so very much interested in the success or failure of the candidates as to suggest that they are helping to find good teachers.

Additional to the entrance tests, President Alger also gives other standard tests, these principally for the purpose of establishing comparative ratings. The revelation of these tests is definitely that the students admitted to Rhode Island College of Education, as a

group, have a rating which is higher than that for admission to reputable standard colleges. When the college course is completed the College of Education has no graduates which it may hesitate to recommend for teaching.

CHARLES CARROLL

STATE DEPARTMENT OF EDUCATION
PROVIDENCE, RHODE ISLAND

MEMORIAL FOR SIR JAMES WALKER

To the Editor

DEAR SIR:

To commemorate the services of Sir James Walker, Professor of Chemistry at the University of Edinburgh from 1908 to 1928, to chemistry in general and to the chemistry department of the University of Edinburgh in particular, it is proposed to establish a fund for a Walker Memorial Lecture to be delivered annually by an eminent chemist invited to Edinburgh by the Edinburgh University Chemical Society for that purpose.

Sir James Walker, who died in May, 1935, was the leading exponent of physical chemistry in Great Britain for nearly fifty years. During the Great War he did valuable work in the manufacture of high explosives, and the new chemical laboratories which he designed and fitted up at Edinburgh are among the foremost, both in equipment and research activity, in this country.

The Chemical Society of the University of Edinburgh enjoys the distinction of being the oldest chemical society in the world, since it has recently been established that it existed as far back as 1785 under the sponsorship of Joseph Black. The Chemical Society of Philadelphia, founded in 1792, has hitherto been regarded as the oldest in the world, but John Morgan, who first taught chemistry at the Medical School of the College of Philadelphia—now the University of Pennsylvania—and Benjamin Rush, one of the signers of the Declaration of Independence, who succeeded him, were both students of Black in Edinburgh, and it is thus highly probable that when James Woodhouse in 1792 founded the Chemical Society of Philadelphia, he was deliberately and consciously following the footsteps of Joseph Black. It is felt that a yearly meeting at which the student members of this august body may have the opportunity of making direct contact with the researches of distinguished investigators in chemistry from other universities will provide a most stimulating permanent memorial of the labors of Sir James Walker for the advancement of the science in Edinburgh and elsewhere.

Former students of Sir James Walker and any others who may wish to assist in the project are requested to send subscriptions to Mr. J. E. Rocca, Honorary Secretary of the Edinburgh University Chemical Society, King's Buildings, West Mains Road, Edinburgh.

JOSEPH E. ROCCA

THE UNIVERSITY
EDINBURGH, SCOTLAND

THE LATE LAMENTED SENATE

To the Editor

DEAR SIR:

May I have a word for the late Senate of Chemical Education? As one who for several years wore too lightly the robe of Senator, conscience demands that the brief obituary notice in the December issue of the JOURNAL (p. 566) be followed by some expression of human emotion for the departed. While it is generally conceded that death occurred several years ago, it was fitting that interment should take place in the Golden West where the deceased first saw the light ten years ago.

It may offend the plebeian sense of propriety to dwell upon might-have-beens on such a solemn occasion, but when the great of earth depart, the dirge, "The king is dead," is often drowned in the shout, "Long live the king." While we have no heir apparent to propose we cannot refrain from some wistful speculation on how the Senate might have met several problems had it preserved its health to this good hour.

Who would deny that the Senate, with its representatives from high school, college, and industry, was better constituted than the Council of the American Chemical Society to deliberate over the question of the qualifications of high-school teachers of science? And yet it was the latter body which at the recent Cleveland meeting of the Society took the first steps toward a solution of that problem.

How the mighty are fallen in the councils of chemical education when the editorial columns of our leading industrial journal must blaze the trail toward some official recognition of those institutions of higher learning best qualified to give adequate professional training. As a result of this prodding it was again the Council (this time at the San Francisco meeting) which initiated the attack upon this academic problem.

And, finally, why should our sister organization, the American Association for the Advancement of Science, through its Junior Academy movement, be left to carry forward single-handed the program of enlistment of the high-school youths in the cause of science? The American Chemical Society essay contests are of blessed memory, but why did the Senate with its ideal set-up of high-school, college, and industrial representation desert the field when the battle had only begun? Did it sense the magnitude of the approaching conflict along this and the other lines suggested, and in cowardice and littleness of its own soul shrivel and die? Heaven forbid! Peace be with its ashes!

JOHN R. SAMPEY

FURMAN UNIVERSITY
GREENVILLE, SOUTH CAROLINA

A. T. Burtsell
F. B. Dains
Tenney L. Davis
J. Howard Graham
B. Clifford Hendricks
J. W. Howard

ABSTRACTS

R. A. Baker, *Abstract Editor*

D. C. Lichtenwalner
Greta Oppe

C. M. Pruitt
Leopold Scheflan
E. D. Walter
E. Roger Washburn
Sidney Weinhouse
G. H. Woollett

KEEPING UP WITH CHEMISTRY

Frosted wool. Anon. *Ind. Bull. Arthur D. Little, Inc.*, **107,** 2 (Dec., 1935).—Until quite recently, the preparation of raw wool was accomplished by an extensive series of washings with soap or other alkali-containing materials. The term "wool scouring" was given to this process. About ten years ago a modification of this age-old procedure was made possible by the use of naphtha as a solvent for removing grease from raw wool. At the present time the use of certain petroleum solvents in the cleansing of raw stock is in commercial operation in a few well-established plants, but it has by no means replaced the traditional wool-scouring method. Now appears a new development which may have a revolutionary bearing on the ancient procedure. This development is a mechanical process designated by the inventors as the "Frosted Wool" process. The raw stock is fed to a conveyor from which it passes through sealing rolls to a continuous belt within a refrigerator chamber. From this belt the frozen stock is automatically delivered to a rotary duster in which the cleansed fiber is separated from the major fraction of its impurities. The wool passes thence to a condenser and through sealing rolls out of the refrigeration unit. It is on the freezing conveyor from 3 to 7 minutes. The operation is continuous and effects in a single operation removal of some 60% to 90% of the vegetable matter contaminating the raw wool, together with 30% to 90% of the wool grease. The process does not effect the removal of all the grease, vegetable, or other foreign material, so that the wool must be scoured, degreased, and washed to yield commercially clean wool; but the final product is reported to be cleaner and softer and also of greater tensile strength. G. O.

Metals in foods. Anon. *Ind. Bull. Arthur D. Little, Inc.*, **107,** 2–3 (Dec., 1935).—In striking contrast to the popular view of metals in foods are the laboratory findings of modern dietitians concerning certain metals commonly regarded with suspicion which have been found to be actually essential to animal or plant nutrition, notably, copper needed for the assimilation of iron. Manganese has been shown to be essential to proper plant and animal development, and is believed to affect the mental outlook. Deficiencies in magnesium result in irritability. Boron, aluminum, silicon, as well as zinc, have been shown to be essential to growth. G. O.

The indigo element. Anon. *Ind. Bull. Arthur D. Little, Inc.*, **107,** 4 (Dec., 1935).—Seventy-two years have elapsed since the discovery of indium, so-called because of its indigo-blue spectrum lines. During most of this period, the supply was exceedingly limited, the price $10 a gram or more, and the commercial applications non-existent. About ten years ago investigations indicated that indium might have value as a surface stabilizer for non-ferrous metals. As a result of this effort, indium may now be purchased for $1 a gram, and after a long search an ore deposit has been found yielding two ounces of indium to the ton, making the metal available in commercial quantities. Indium is a silvery white, lustrous metal, soft enough to yield to the pressure of the fingers or to be cut with a knife, malleable enough to be pounded into thin sheets, with a melting point so low that the flame of a match will melt it. It has the softness of lead, the density of zinc, and the luster of silver. Chemically, it resembles aluminum and zinc. It does not tarnish in air or water. It forms many compounds, forms an amalgam with mercury, and alloys with silver, platinum, gold, and certain other metals. Indium is being added at the present time to certain precious metal dental alloys to increase hardness and tarnish-resistance. It is permanently tarnish-resisting when plated, and the resulting plate is capable of excellent reflectivity and is finding some application in the finishing of reflectors for store windows, as display lights, and also as automobile headlights. When 18% of indium is added to Wood's metal, the resulting alloy has a melting point so low that the metal may be poured without discomfort upon the bare skin. This alloy offers itself for small casts and possible surgical molds. The low melting point, high boiling point, and high coefficient of expansion indicate that indium may find a use in high-temperature quartz thermometers. An unexploited field is that of organic and inorganic compounds of indium for dyes and medicines. G. O.

Seeking a working language for odors and flavors. E. C. Crocker. *Ind. Eng. Chem.*, **27,** 1225–8 (Oct., 1935).—"An instrument that can detect a millionth of a milligram, and in some cases less than a billionth of a milligram, of the vapor of hundreds of kinds of organic substances should inspire our admiration. That instrument, with its spectroscopic sensitivity and great convenience of operation, is the human nose. There should be both commercial and scientific value in a better understanding of the nature of odor and of the mechanism of smelling, as well as in an adequate, logically founded language for odor description."

The importance of smell is readily recognized by organic chemists. Leakages, toxic vapors, fires, are often detected. A sniff at the stopper often confirms the label. Taste and smell often confirm the quality of food. With the perfume chemist, smell is of prime importance. In recent years, the demand for odorless products has been increasing. In spite of the importance of odor, industrially and esthetically, descriptions in chemical handbooks are pitifully inadequate.

"In tasting, very small quantities of certain chemicals produce distinct impressions, but the quantities required for minimum taste perception are gross compared with those for smell perception. From 1-cc. sips, one can just detect the sweetness of 0.7 per cent. cane sugar solutions. Thus the taste threshold for sugar is about 7 mg. The lower limit for salt is about 1.5 mg., and for tartaric and other acids is of the order of 0.2 mg. Passing to materials of the strongest taste, the limit for caffeine is 0.04 mg., for quinine 0.016 mg., and for saccharine 0.012 mg. Roughly, the limit for a taste of the most powerful stimulus known is not far from 0.01 mg."

About 100 cc. of air must be sniffed for ordinary odor discernment, although half this amount will register if the odor is strong. Fair quotes detectable concentrations in air for some of the most odorous chemicals in milligrams per liter:

Chlorophenol	0.000,004
Ionone	0.000,000,1 to 0.000,000,05
Artificial musk	0.000,000,04 to 0.000,000,005
Vanillin	0.000,000,5 to 0.000,000,000,2

If 0.000,000,000,1 mg. per liter is taken as the ultimate in dilution which is perceptible, the amount per sniff is of the order of 0.000,000,000,01 mg. The sense of smell is thus many million times more delicate than the sense of taste. However, smelling does not approach single-molecule sensitivity, for in 0.000,000,000,01 mg. of vanillin there are 4×10^7 or 40,000,000 molecules. If only 1 molecule in 1000 of those sniffed falls on the sensitive area, some thousands are necessary to give a smell impression, even with this most actively odorous agent.

The author has divided odors into four types:

1. Fragrant or sweet
2. Acid or sour
3. Burnt or empyreumatic
4. Caprylic or œnanthic

"Besides reduction of the number of apparent fundamentals, the present workers devised a semi-quantitative numerical arrangement whereby any odor may be expressed as a four-digit number—for instance, 3803 for acetic acid, 8445 for benzyl acetate, or 6323 for α-terpineol—where the successive figures are for the four types, fragrant, acid, burnt, and caprylic, in succession, on the basis of 8 for most powerful and 1 for just detectable."

"The chief value of a better system of odor analysis and classification will be the basis it will provide for a real language of odor. Odor impressions are now entirely too personal, and terms are

not in general use which can convey odor impressions accurately from person to person, verbally or by written record."

D. C. L.

Columbium and tantalum. C. W. BLAKE. *Ind. Eng. Chem.*, **27,** 1166–9 (Oct., 1935).—Tantalum, first developed in Germany for use in lamp filaments, was later replaced by tungsten, and but little use was made of it until recently. Ta and Cb are always found together. Richest deposits of Ta are found in Australia containing 60% tantalum oxide and 15% columbium oxide.

"Tantalum and columbium, from the minerals tantalite and columbite, are separated from each other by the recrystallization of their double fluorides with potassium. The electrolysis of the fused double fluorides yields the respective metals in the form of finely crystalline powder. These powders are heat-treated in vacuum furnaces to produce ingots of the metals which are then capable of being rolled into sheet or drawn into wire at room temperature."

Ta is preferred to Cb for most purposes due to lower cost and its greater resistance to chemical corrosion. Both are used in construction of power and vacuum tubes. Ta is not attacked by HCl, HNO_3, aqua regia, or chlorine. Methods of hardening have been developed by which the degree of hardness and depth of penetration can be varied through wide ranges and readily duplicated.

Ta has been used in the construction of stirrers, stills for acids, lining for pipes to conduct HCl and hypochlorites, needle valves for use in water chlorination, and, on account of its hardness, as spinnarets for rayon spinning. Tantalum carbide is used in the manufacture of hard carbide compositions for cutting tools, wire dies, and abrasion-resisting surfaces. D. C. L.

Variation in the composition of the atmosphere with altitude. R. E. D. CLARK. *Sch. Sci. Rev.*, **17,** 8–21 (Oct., 1935).—In spite of mathematical calculations, which predict a variation in the composition of the atmosphere with altitude, observational data obtained by means of balloon ascensions show the composition to be tolerably constant up to a height of at least 11 km. This constancy has been readily explained by meteorologists. Masses of air are constantly rising and falling as a result of local heating, thus causing a mixing which is more rapid than the separation of the gases by gravity. The only successful approach to the problem of atmospheric composition at relatively high altitudes (80–200 km.) has been through spectral studies of the aurora. These indicate that even at these high altitudes vertical winds keep the atmosphere so well mixed that no changes of composition are possible. S. W.

APPARATUS, DEMONSTRATIONS, AND LABORATORY PRACTICE

Chemical plant construction of the present and future. H. S. JACOBY. *Chem. & Met. Eng.*, **42,** 654–7 (Dec., 1935).—Many changes in building construction have come about through experimental approach rather than through scientific research. Research in building materials has a long way to go before it reaches the consumer.

The correct determination of a building site is intimately related to soil conditions. Equipment has been developed to determine the nature of the subsoil and within close limitations the depth to which piling need be driven to carry loads safely.

Although various cements have been developed to resist chemical action and constant wear, the prime essential for successful concrete work is to secure the proper mix of cement, water, and aggregate. Stronger concrete is now made with less cement. Future research should develop a concrete with greater tensile strength.

Stronger brick with smoother edges and corners and 50% less moisture absorption is now made by de-airing.

Steel sash is in evidence in nearly all new chemical plants. The chemical engineer still prefers abundant light and ventilation to a windowless factory. A non-condensing and free-from-drip window glass would be useful.

Wood is still the most accessible and adaptable of building materials. A treatment is needed to make lumber fireproof.

J. W. H.

Industrial medicine and toxicology make for safer plant operation. G. H. GEHRMANN. *Chem. & Met. Eng.*, **42,** 672–5 (Dec., 1935).—Modern civilization demands that we improve the old methods by which workmen were made ill and died by the score and that we devise adequate methods of preventing occupational poisonings and diseases. Industrial medicine should provide complete pre-employment examinations, protection of employees by periodic examinations, and treatment of occupational diseases when they occur.

No industrial medical program can be properly devised without first obtaining a complete picture of the toxicology. This toxicology reveals the toxicity of chemical compounds, the mechanism of their action, the organs affected, and symptoms to be expected.

There is no material, regardless of its toxicity, which cannot be handled with safety, provided the toxicity is understood and proper methods of handling instituted. J. W. H.

Coal-tar oils for internal combustion engines. C. H. S. TUPHOLME. *Chem. Industries*, **37,** 549 (Dec., 1935).—The chief advantage of a tar-oil fuel to the user is its low cost compared with petrol. Tar-oil fuels make the best showing when they are employed in vehicles covering long journeys with relatively few stops. Tar-oil fuel appears to have no great effect on the liveliness, acceleration, and hill-climbing ability of an engine or vehicle, especially when the engine is hot. Similarly, most users have found that maximum speed is unaltered. The exhaust gases have generally a pronounced odor of creosote but are clear under normal running conditions. One good feature is shown by the exhaust gases from engines running on tar oil, namely, the comparative absence of carbon monoxide. A. T. B.

Use of chemicals in mob control. R. E. SADTLER. *Chem. Industries*, **37,** 551–2 (Dec., 1935).—The use of chemicals is the most humane and most efficient method yet devised for the suppression of internal civil disorders. The use of non-toxic gas, or tear gas, is authorized, but toxic gases such as phosgene or materials like white phosphorus are prohibited. A persistent tear gas, like brombenzylcyanide, is used when it is desired to deny the streets to a mob or force them to evacuate a certain area. On the other hand, a non-persistent tear gas, such as chloracetophenone, is used when permanent effects are not desired. For successful use of non-persistent gases, it is essential to build up a high initial concentration by rapid fire and then maintain the gas cloud by a reduced rate of fire. A slow rate of fire is sufficient to build up a good concentration of persistent gases. There are no serious after-effects following exposure to tear gas in field concentrations. Those exposed to tear gases should get in a gas-free atmosphere as soon as possible and their eyes will clear in five or ten minutes. A. T. B.

Now the steamlined watch glass. ANON. *Laboratory*, **7,** 42–3 (Dec., 1935).—This watch glass, which was designed by Edgar B. Read, of the Mellon Institute of Industrial Research, is equipped with three ribs on the underside. Resting on the edge of the beaker these ribs raise the cover enough to let the steam escape at practically the same rate as from an uncovered beaker. A. T. B.

A new blood sedimentation pipet. ANON. *Laboratory*, **7,** 40–1 (Dec., 1935).—The new Brooks pipet is a straight glass tube, of 1 to 1.5 mm. bore with ground glass tip for attachment of a hypodermic needle. A stopcock cutting the lumen of the pipet exactly 100 mm. from this tip divides the pipet into two parts. A rubber tube with mouthpiece attached to the shorter end can be used for filling and flushing the pipet. A. T. B.

The Beckmann pH meter (glass electrode). ANON. *Laboratory*, **7,** 38–9 (Dec., 1935).—The glass electrode has a comparatively heavy membrane and can be handled very much like an ordinary piece of glassware without breaking, and no delicate galvanometer is required for measuring the current. This has been made possible by replacing the galvanometer with a specially designed vacuum-tube amplifier. The replacement of batteries, standard cell, or vacuum tubes offers no difficulties. A. T. B.

Stop that stopper. ANON. *Laboratory*, **7,** 46 (Dec., 1935).—A strong rubber tie about four inches long extending into a loop at each end can be purchased for less than a nickel and will handcuff a stopper or a stopcock to the piece of glassware, thus minimizing loss and breakage. A. T. B.

New machine measures grindability. ANON. *Laboratory*, **7,** 44–5 (Dec., 1935).—The Hardgrove Grindability Testing Machine is described in detail in a pamphlet which can be had upon application to the Fisher Scientific Co. A. T. B.

A home-made Kipp apparatus. J. H. H. MACRAE AND T. T. RICHARDS. *Sch. Sci. Rev.*, **17,** 137 (Oct., 1935).—A glass tube (length 5 in., diam. 1 in.) which stands upright in an Erlenmeyer flask of 800-cc. cap. is filled to a depth of 1 in. with broken glass and then with ferrous sulfide. The flask is sealed with a rubber stopper. The acid is contained in a similar flask placed above

the first one and connected to it by a glass siphon tube which passes through the rubber stopper to the bottom of the flask. The other hole of the stopper contains a bent outlet tube for the gas and is closed by means of a pinch-clamp. The siphon is started by applying suction to the outlet tube, after which the apparatus works automatically. S. W.

Determination of the parachor. E. J. WILLIAMS. *Sch. Sci. Rev.*, **17**, 22–5 (Oct., 1935).—The parachors of various liquids may be determined within the usual time allotted to a laboratory experiment. A Westphal balance is used in determining the density, and the surface tension relative to water is found by means of a stalagmometer. Students' results for allyl alcohol, nitrobenzene, and ethyl cinnamate are given, showing good agreement with calculated values. S. W.

TEACHING OBJECTIVES, METHODS, AND SUGGESTIONS

Very elementary chemistry—a weekly chronicle. ANON. *Sch. Sci. Rev.*, **17**, 26–35 (Oct., 1935).—An instructor's account of his experiences in teaching chemistry to 11-year olds in an English elementary school. S. W.

The preparation and presentation of a science-night program. R. COLLIER, JR. *Educ. Screen*, **14**, 217–22 (Oct., 1935).—Science night is suggested as a very tangible method of "selling our school" to its public. Details of organization, of publicizing its offerings, of handling the crowd after it arrives, and of securing the coöperation of different departments are presented. While the departments handling the sciences carried the burden of the program, other departments such as Art, Latin, English, and the library contributed. In addition special exhibits of some local industries and a hobby show may well be used, particularly if those in charge feel a need for greater variety to their offerings. B. C. H.

"Studies of laboratory methods of teaching," by R. W. LEIGHTON (Part I) and **"Qualitative aspects in the improvement of science teaching,"** by ROBERT H. SEASHORE (Part II). Edwards Brothers, Ann Arbor, Michigan, 1935. viii + 184 pp. B. D. WOOD. *J. Higher Educ.*, **6**, 397 (Oct., 1935).—Ben D. Wood, Columbia University, in reviewing this volume tells us that the first part contains a report of an experiment conducted at the University of Oregon to determine the relative effectiveness of different laboratory technic for attaining desired outcomes of science teaching. The authors say that the results of experiments indicate that either close supervision of laboratory work, or no supervision at all, brought best results in general.

Attention is called to the need for further revision of science-teaching procedures, in order to make them conform to the needs of individual students rather than to those of subject matters.

The second part of this volume outlines "the procedure for improving a particular elementary-science course in the matter of objectives, content of the course, methods of presentation, and evaluation or measurements of results." A. T. B.

A reason for study. R. I. JOHNSON. *J. Higher Educ.*, **6**, 352–6 (1935).—Mr. Johnson points out that we are all familiar with the formula which calls for planning, performing, and appraising; then he suggests that we amend the formula to read: purposing, planning, performing, and appraising. Even the universal school activity of reading takes on new interest, and students show improved comprehension when definite purposes are supplied for the specific reading activities. The student should feel that the teacher knows why he is making each assignment. Teachers and students alike must be cognizant of a cause for study; they must not only honor the question "Why?" when it arises in connection with units of study—they must invite the question and face it frankly. A. T. B.

EDUCATIONAL MEASUREMENTS AND DATA

Aiding the fit. C. G. WRENN. *J. Higher Educ.*, **6**, 357–63 (1935).—Students of above-average intelligence are the subject of this report. Their maladjustment is discussed and a program to correct this maladjustment is suggested by the author.

Among other items of interest we learn that students who had high Thorndike scores, that is, 93 or above, practiced certain habits of work that were different from those of students who had relatively low Thorndike scores, that is, 75 or below, but who had achieved the same scholarship results. Students with high Thorndike scores who were in the upper 10 per cent. of scholarship seemed to practice the following five habits of study:

(1) They make a rapid survey of the whole reference to find out what it is about before studying it more intensively.
(2) They are careful to take note of main and paragraph headings, italicized material, and summary.
(3) They recite material studied to themselves, rechecking any doubtful points.
(4) They try to relate material learned in one course to that learned in others.
(5) They try to get each point as they go over it rather than going on at the time and then coming back to clear up doubtful points.

On the other hand, those students with low Thorndike scores who were also in the upper 10 per cent. of scholarship practice more consistently than the first group the following five habits of study:

(1) They take lengthy notes, writing almost continuously during the lecture hour.
(2) They copy lecturers' words as nearly verbatim as possible.
(3) They have trouble in picking out the significant points in the materials read.
(4) They make a time budget.
(5) They mark or underline the text.

Mr. Wrenn says if it were possible to make a subjective interpretation of the possible desirability of certain habits of study one might conclude that students with high Thorndike scores practice habits of study that are considered psychologically more desirable than those practiced by students with low Thorndike scores. The students with low Thorndike scores attained their high scholarship by a more careful use of their time and by what one might suspect as sheer memorizing of material, and yet these may be the most adequate means by which such students can maintain high scholarship. A. T. B.

THE PHILOSOPHY OF SCIENCE

Physical science and the principle of causality. W. J. SPARROW. *Sch. Sci. Rev.*, **16**, 449–57 (June, 1935).—In the scheme of classical physics all happenings in the world of matter were supposed to take place according to fixed and unequivocal laws, and the physical world was held to be completely determined. Even when statistical methods became necessary to deal with vast concourses of atoms and molecules, *e. g.*, Boltzmann's treatment of the second law, these were considered to be merely devices. However, the introduction of the quantum theory has led to a completely new orientation of thought in these matters. First, by the discovery of new phenomena such as the process of radioactive decay, the absorption and emission of light by atoms, etc., which are apparently not subject to the causal principle; and second, by a fuller consideration of the older laws, Eddington, Jeans, Heisenberg, and Bavink have been led to abandon the principle of causality as a scientific doctrine. On the other hand, Einstein, in agreement with Planck, believes that, while strict causality has failed us for the moment, the fault lies mainly in our inadequate formulation of the principle. S. W.

The need for a philosophy of science. H. DINGLE. *Sch. Sci. Rev.*, **17**, 1–7 (Oct., 1935).—That we live in an age of science is a remark as trite as it is fundamentally untrue. While the word and the associated activities and the veneration are everywhere, the spirit of science is confined to the narrow cell of abstract research.

The impartial and dispassionate collection of data which we call the scientific attitude should be brought into relief as an attitude appropriate to all human affairs. This is a problem for the universities. The teaching of scientific subjects must be supplemented by the inclusion of philosophy of science, in order to show that scientific principles are not goddesses to be worshipped but handmaidens to be directed; and to discover how far and in what manner they can best be directed in the tasks of life as a whole. S. W.

RECENT BOOKS

LIFE AND EXPERIENCES OF A BENGALI CHEMIST, VOLUME II. *P. C. Rây.* Chuckervertty, Chatterjee & Co., Ltd., Calcutta, 1935. viii + 469 pp. 14 × 21 cm. 6s.

The first volume was largely chemistry and the space given to politics was not unreasonably large. The second volume is devoted almost completely to savage attacks on English rule in India. It should have been called "Political Opinions of a Bengali Chemist."

One can sympathize with the author's feeling that English should be used less and the vernacular more. "The last occasion when I sat on the jury box, *i. e.*, before I had completed my sixtieth year, there was a sessions case of which I was chosen foreman. The judge was a Bengali and a former pupil of mine. The accused was a Bengali; the Advocate General, the Standing Counsel were all Bengali barristers, besides an Eurasian barrister, who of course knew Bengali. There was the farce of the evidence in each case being translated by the Court interpreter before it could be 'heard' by the judge and the jurors. This had the effect of protracting the trial to an unusual length," p. 63.

One wonders whether there may not be another side to the criticisms in regard to railway embankments, p. 156. "The floods of this year in Orissa and Midnapore, and water-logging in the suburban area of Calcutta illustrate the disastrous results of the government policy in regard to canal embankments. The root cause is the same, namely obstruction to natural passages of water on account of embankments raised for setting up cheap lines of communications. Canals are sketched out on a map in straight lines. No consideration is given to the drainage of the surrounding lands. Some sluice gates are kept for draining flood water but they are either inadequate or inoperative; and mostly the canal leads and embankments are designed in such a way that the sluice gates are mere eyewash, for they cannot receive the drainage from the surrounding lands—they are not designed to do so."

The author claims, p. 243, that famines and pestilences "which levy such a huge toll every year in ill-fated Bengal were scarcely known six decades ago; somehow or other they have synchronized with British rule. Tuberculosis has no doubt been endemic in India from time immemorial; it is mentioned as Râja Yakshâ in the ancient Ayurvedic works but its victims were few and confined chiefly to old age; whereas this scourge is now spreading like wild-fire."

"As has been shown above, the spread of malaria has followed in the wake of drainage obstruction due to railway embankments. Dr. Bentley, while laying stress upon this aspect, has not hesitated to call it also *hunger disease*. Malnutrition, which brings on debilitated constitution and deprives the victim of resisting power, is equally responsible for the havoc of malaria and tuberculosis. Water famine has also followed in the wake of the British rule."

WILDER D. BANCROFT

CORNELL UNIVERSITY
ITHACA, NEW YORK

ESSENTIALS OF PHYSIOLOGICAL CHEMISTRY. *Arthur K. Anderson,* The Pennsylvania State College. John Wiley & Sons, Inc., New York City, 1935. v + 257 pp. 31 figs. 15 × 23 cm. $2.75 net.

The author has undertaken a difficult task, *i. e.*, to present the more important facts of biochemistry as related to the animal body in a form which will be understandable to students with limited preparation in chemistry and biology. He states it as his opinion that a thorough knowledge of the chemistry of biological compounds is a prerequisite to an understanding of biochemistry. He therefore emphasizes the chemistry of the carbohydrates, lipids, and proteins more than is usually done in elementary books in this field.

In a preliminary chapter on physical chemistry the author has, in the judgment of this reviewer, presented simply and clearly those principles that students must understand before the essentials of physiological chemistry mean anything to them.

The text presupposes some sort of course in organic chemistry, but the chapters on carbohydrates, fats, and proteins are presented in such fashion that even with very little previous training the essential facts about the chemistry of these compounds may be understood.

References, while not numerous, are well selected.

We believe that in the chapter on blood the part on Respiration and Alkali Reserve could be improved. Altogether the book is readable and teachable. It will probably take its place as a simple presentation of the essentials of physiological chemistry where such courses are offered to students in home economics and related fields.

WORTLEY F. RUDD

MEDICAL COLLEGE OF VIRGINIA
RICHMOND, VIRGINIA

A HISTORY OF SCIENCE, TECHNOLOGY, AND PHILOSOPHY IN THE XVITH & XVIITH CENTURIES. *A. Wolf,* Professor and Senator, University of London, Head of the Department of History and Methods of Science, Former Fellow of St. John's College, Cambridge, Fellow of University College, London, Co-editor of the Encyclopædia Britannica; with the coöperation of *Dr. F. Dannemann,* Professor in the University of Bonn, and *Mr. A. Armitage,* of University College, London. The Macmillan Company, New York City, 1935. xxviii + 692 pp. 316 illustrations. 15.3 × 24.7 cm. $7.00.

This book contains a comprehensive account of the growth of natural knowledge during the sixteenth and seventeenth centuries, of the practical applications which were made of that knowledge, and of the contemporaneous philosophical speculations which were based upon it or somehow arose in consequence of it. These last are especially important for a proper understanding of the history of science. Locke's doctrine of primary qualities, for example, had much to do with preparing a way for the chemical revolution accomplished by Lavoisier, with producing a state of mind for which quantitative considerations based upon measurements of weight were of the greatest significance. The book is truly an account of European history during the sixteenth and seventeenth centuries—not political history, for the kings of the time, the battles, and territorial boundaries affect us scarcely more than does last year's snow—but real history in being an account of what men were thinking, doing, and hoping to do. It contains chapters on a number of subjects which have not been treated heretofore in the histories of science. We are particularly glad to see those on exploration, on psychology, and on the social sciences. It is altogether a well-rounded book. Although "its primary aim . . . is to meet the needs of the serious student," it is easy and interesting to read, good for the perspective of the cultivated individual, and good for the not-yet-serious student who, if he picks it up, is likely to come back to it again.

The subjects of the chapters are as follows: I. Modern Science; II. The Copernican Revolution; III. Galileo Galilei; IV. Scientific Academies; V. Scientific Instruments; VI. The Progress of Astronomy: Tycho Brahe and Kepler; VII. The Newtonian Synthesis; VIII. Astronomers and Observatories in the Age of Newton; IX. Mathematics; X. Mechanics; XI. Physics: Light; XII. Heat, Sound; XIII. Magnetism and Electricity; XIV. Meteorology; XV. Chemistry; XVI. Geology; XVII. Geography: Exploration, Cartography, Treatises; XVIII. The Biological Sciences: Botany, Zoölogy, Anatomy and Physiology, Microscopic Biology; XIX. Medicine; XX. Technology: Science and Technology, Agriculture, Textiles; XXI. Building Materials; XXII. Mining and Metallurgy, Mechanical Engineering; XXIII. The Steam Engine, Mechanical Calculators; XXIV. Psychology; XXV. The Social Sciences; XXVI. Philosophy.

The book is a good all-round treatment of its subject; it touches on most of the principal points. A student of the history of chemistry or of sociology, or of any one of the special sciences, will probably find that it contains little or nothing on his subject which is new to him. He will discover gaps in the treatment of his science but will see it exposed in its relations to others in a manner which would be impossible in a book devoted to a single one of them. The chapter on chemistry contains accounts of iatrochemistry and the beginnings of chemical science, of Libavius, van Helmont, Glauber, Rey, Boyle, Hooke, Lower, Mayow, and of the discovery of phosphorus. Several of the chemists appear in other connections in other chapters. The account of Boyle fails to make it clear that "The Sceptical Chymist" is devoted primarily to a search for a criterion by which it may be determined experimentally whether a given substance conforms to the definition of element or not. The words, atom and corpuscle, do not appear in the index. We have found no mention of the fact that Boyle in "The Sceptical Chymist" and elsewhere argues for a corpuscular theory of matter, and none of Boyle's discovery of methyl alcohol and of acetone. In the chapter on philosophy, excellent summaries are given of the methodology of Bacon and of Newton.

The book is handsomely printed on cream-colored paper, and abundantly illustrated.

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

CRYSTAL CHEMISTRY. *Dr. O. Hassel*, Lecturer in Physical Chemistry in the University of Oslo. Translated from the German by *R. C. Evans*, B.A., Ph.D., B.Sc., Demonstrator in Mineralogy and Petrology in the University of Cambridge. William Heinemann Ltd., London, 1935. Chemical Publishing Co. of New York, 175 Fifth Ave., New York City, exclusive agents in North and South America. ix + 94 pp. 9 figs. 13 × 21 cm. $3.50.

Chemical education in the past has to a large extent been concerned with relationships between the properties of substances and the *kinds and relative numbers* of the atoms of which these substances are composed. In organic chemistry, it is true, the dependence of the properties of substances on the *relative arrangements* of the atoms and the dependence of these arrangements on the kinds of atoms are also studied, but in inorganic chemistry the structural side of the subject has been almost entirely neglected. The reason, of course, is that until recent years a sufficient body of knowledge of inorganic structures has not been available. Now that the structures of hundreds of crystalline substances are known, however, it would seem that the structural relationships should occupy as important a place in inorganic chemical education as the relationships between formulas and properties; a true *understanding* of chemistry is otherwise impossible.

The chief difficulty in the way of remolding our chemistry courses to include this new knowledge is the fact that none of the textbooks now published are suitable. Although a few descriptions of various structure types are usually given, real structural chemistry is almost entirely neglected. Sometime in the future this lack may be remedied, but for the present any teacher wishing to incorporate this new viewpoint in his teaching—or in his thinking—must turn to journal articles or to such books as the one under review. Although by no means ideal for this purpose, it is one of the few not-too-technical works on the subject.

This book is primarily concerned with the principles determining the types of structure assumed by elements and compounds rather than with relationships between structure type and properties. (For the latter there is no good treatment available.) For the most part it deals with relationships between the sizes and charges of *ions* and the types of arrangement found in compounds containing these ions. On the whole the subject is well treated, although (in common with most other writers in this field) the author attempts to treat as ionic many substances in which the atoms are undoubtedly held together by bonds of a (more-or-less polar) covalent character. The rôle of the covalent bond in crystal structures is treated, very inadequately, in only one short chapter.

Among the most valuable chapters for the chemistry teacher is that on "The Crystal Chemistry of the Silicates." Previous to the X-ray work on these compounds, this field, in spite of its industrial importance, was about the least understood in all inorganic chemistry. Now it is among those best understood. Except for the neglect of electron-pair sharing, the subject is well presented here.

The book is clearly written, easily understandable to the nonspecialist. In a few places, however, the reader is apparently expected to be familiar with certain crystal structure types which are neither illustrated nor described. A few figures illustrating these structures would help. Some of the diagrams which are given are also insufficient without accompanying description to convey to a layman a true conception of the structures they represent.

MAURICE L. HUGGINS

THE JOHNS HOPKINS UNIVERSITY
BALTIMORE, MARYLAND

OUTPOSTS OF SCIENCE. *Bernard Jaffe.* Simon and Schuster, New York City, 1935. xxvi + 547 pp. 15.5 × 23.5 cm. Freely illustrated with halftones and line cuts. $3.75.

In the reviewer's opinion this book gives marked evidence of the growth and ripening of the author's literary and scholarly powers since the appearance of "Crucibles." And, be it understood, this comment should not be interpreted as derogatory to the earlier work.

The plan followed in the attempt to present a bird's-eye view of present-day scientific research is best revealed by extracts from the author's introductory statement.

"First I was to follow through an intensive reading program which would make it possible for me to pick out the men who had done the most crucial work in each field. This reading project was to be reinforced by conversations with numerous scientific men whom I knew in New York. For various reasons, such as the intrinsic difficulty of the subject, the lack of general interest, and the paucity of scientific experimentation I abandoned such fields as relativity, geology, and psychology and finally selected the topics which comprise the contents of this book....

"Having listed the men I wanted to see, I mapped out an itinerary—a wide circle around the United States which would bring me to about fifty of the most important research laboratories in the country. In September, 1932, I started from New York on a scientific pilgrimage to the firesteps and outposts of the present battlefronts of science in America. I was armed with little more than an impertinent belief that eminent men busy in scientific workshops might stop for a while to tell me what they were doing and hoping so that the general public might catch a glimpse of the many new discoveries....

"It had been planned that the leaders in each field of science whom I had met were to correct those portions of the manuscript dealing with their own work. This would, of course, insure a greater measure of authenticity for the book. This plan was carried through with but one exception. The chapter on Physical Disease reached Baltimore the day on which Dr. William H. Welch died in his eighty-fourth year. Dr. Fielding H. Garrison, the eminent historian of the Institute of the History of Medicine of The Johns Hopkins University, and a close friend of Welch, was kind enough to edit the historical material of this chapter and Dr. Coleman B. Rabin of Mt. Sinai Hospital, the clinical data."

Chapter I, on Genetics, deals in large part with the researches of Thomas Hunt Morgan. Chapter II, Anthropology, emphasizes the work and opinions of Aleš Hrdlička. Chapter III, Physical Disease, is written around the life and work of the late William H. Welch, but appropriately enough, shows considerable breadth of historical outlook. The mouse-breeding experiments of Maud Slye constitute the principal theme of the chapter on Cancer (IV). Chapter V, Glands, is a summary of hormone research, with

particular emphasis on the work of John Jacob Abel.

Other chapters and the research workers featured are as follows:

VI, Mental Diseases—Adolf Meyer
VII, Vitamins—Elmer V. McCollum
VIII, Insects—Leland O. Howard
IX, Matter—Robert A. Millikan
X, Radiation—Millikan and Arthur H. Compton
XI, Astrophysics—George Ellery Hale
XII, Weather—Charles G. Abbot and Andrew E. Douglass
XIII, Galaxies—Hubble, Humason, and Tolman

There is a bibliography of sources and references and an index.

The book should be considered as a sampling of scientific achievements and scientific personalities rather than as a comprehensive report upon the present status of scientific research. It is written in a style which is interesting because it reflects the author's own interest, and which is refreshing because it appears to be natural. Some scientific inaccuracies will be noted, but the general picture is faithful.

OTTO REINMUTH

QUALITATIVE ANALYSIS. *H. S. Moodey*, Senior Science Master at Hampton Grammar School. William Heinemann Ltd., London, 1933. Chemical Publishing Co. of N. Y., Inc., exclusive agents in North and South America. ix + 182 pp. 15 figs. 16.5 × 21.5 cm. $3.00.

This book is written with the ideas in mind that one must have a fairly extensive acquaintance with the laws of physical chemistry to understand the reactions of qualitative analysis and that the study of physical chemistry in our better preparatory schools can, to quite a degree, be centered around qualitative analysis. An attempt is made to give a condensed survey of all physico-principles that are at all germane to the study of qualitative analysis.

The book begins with an explanation of the law of mass action based on the kinetic theory of gases. Mention is made on the first page of the work of Clausius, Clerk Maxwell, Bragg, Debye, Guldberg, and Waage; van der Waals' equation for expressing the gas laws of Boyle and Charles is explained in the very first paragraph. About the first third of the book consists of general chemical theory with very little suggestion with respect to practical applications of this theory in qualitative analysis. Topics such as ionization, hydrolysis, chemical affinity, colloids, and very recent chemical theory with respect to the constitution of matter are discussed briefly in a way that indicates familiarity with the literature. Actual laboratory practice covers only about one hundred pages and after an explanation of the spectroscope, the book ends with a discussion of spot tests with organic reagents as developed by Feigl. Here the formulas of about twenty rather complicated organic compounds are given and the use of these compounds as reagents is explained.

The directions for carrying out analyses are clear and the procedures recommended are good. Pictures show how to filter, wash a precipitate, transfer a precipitate from beaker to a filter, use the blowpipe and make charcoal, bead and flame tests. Considerable stress is laid on the preliminary examination of solids and it is recommended to test for anions before cations.

The book is assumed to provide all information necessary to enable a high-school pupil to analyze any substance which the instructor is likely to give him. The discussion with respect to handling difficult silicates, oxides such as tinstone, or artificial substances such as carborundum are hardly adequate, but in most cases the results will compare very favorably with those obtained in the better high schools and academies of this country.

This little book shows very clearly that in England, as in the United States, excellent teachers of chemistry are to be found in the preparatory schools. In the colleges, emphasis is often placed upon a man's ability to accomplish research and the work of teaching beginners is often given to graduate students who have had little teaching experience. In the preparatory schools more emphasis is placed upon the ability to train students, and teachers there realize that modern chemical theory can be grasped by youngsters in the high school just as readily as by students who have been brought up on out-of-date theory and perhaps already have a college degree.

Teachers of chemistry will do well to examine this book, as it will help to explain how a young lad of fifteen can come to this country from England and obtain the Ph.D. degree here after six years of further study. Most teachers will feel that physical chemistry is over-emphasized but the text is modern, although suitable respect is paid to the older chemical art. It is to be regretted that most college instruction is not as adequate as this little book is with respect to blowpipe assay.

WILLIAM T. HALL

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PHYSICAL CHEMISTRY. *A. J. Mee*, M.A., B.Sc., Senior Chemistry Master, Cheltenham Grammar School. William Heinemann Ltd., 99 Great Russell St., London, W.C. 1., 1934. Chemical Publishing Co. of N. Y., Inc., 175 Fifth Ave., New York City, exclusive agents in North and South America. xix + 780 pp. 213 figs. 5 halftone plates. 14 × 21.5 cm. $7.50.

"This book sets out to give an up-to-date outline of the resulfs and methods of Physical Chemistry." This objective, ambitious enough for a single volume, has been realized very satisfactorily. However, "The book is suitable for students who are preparing for the Higher School Certificate and Intermediate Science Examinations of the various Universities, for University Scholarships and for University Degrees up to Pass standard." Even allowing for the differences between the English and American systems of instruction, this seems to place too heavy a burden on a single text. Professor Mee contends, "There is no need to emphasize the value of using one text-book for all the examinations enumerated above," and does suggest an abbreviated course for the first two applications. But the book contains such a wealth of information that it must be rather appalling to the beginner.

The arrangement is unusual. First there is a critical discussion of the laws of chemical combination and of atomic-weight determination. This is very desirable. It is omitted from too many texts. Then follow two chapters on atomic structure. These cover such subjects as the conduction of electricity through gases (including as it does a multitude of subjects), radioactivity, isotopes (detection, separation, nuclear structure, etc.), deuterium, atomic transmutation, neutrons and positrons, quantum theory, wave mechanics, spectral series, ortho and para hydrogen, etc. Next comes an excellent chapter on valency. Gases, liquids, and solids follow in orthodox order. However, the discussion of liquids includes many of the additive and constitutive properties, related to structure, that are commonly discussed elsewhere. A brief discussion of the correction of boiling points for pressure changes is included. This is most commendable. Very few texts in physical chemistry treat it formally. The discussion of the parachor is excellent. Unusual in the average text is a very good discussion of polymorphism, Smit's theory of allotropy, and intensive drying. These are grouped in the chapter on solids. Chemical kinetics and homogeneous equilibrium are discussed together. This is good pedagogy. They are followed by the phase rule. Chapters X and XI treat of solutions and dilute solutions in very satisfactory fashion. Noteworthy is the inclusion of metallic conductivity with electrolytic conductivity. Ionic equilibria are discussed rather fully, including remarks on the Debye-Hückel theory. A chapter on acids, bases, and salts includes the modern extended theory of the same. The chapter on thermochemistry is good but that on energy and chemical reactions only fair, including as it does formal thermodynamics and electrochemistry in but 36 pages. It seems that at least double the space might have been allotted with subdivision into two chapters. The chapters on colloids, catalysis, and photochemistry are very good indeed and that on the structure of simple molecules unusual in such a work. The latter includes Raman spectra, electron beams, and the dipole moment.

Little is omitted from this book, the most serious omissions being the oil-film experiments of Langmuir, Adam, and others, and the matter of liquid junction potentials. There is likewise a lack of original literature references. Partly because of the unusual order of discussion and partly because of the great amount of information contained in it, the book gives one the feeling of sitting down at a big dinner where all the food is served at once. A more orderly display of viands would probably result in greater consumption with less undesirable after effects.

Particularly noteworthy and commendable are the following: There is a *detailed* table of contents. This is missing in the majority of texts. It is in addition to the usual subject and author indexes. The book is abundantly cross-referenced. Many chapters include a rather full discussion of methods. Every chapter (or subchapter) is followed by a compact summary. This is a very valuable innovation. Likewise each chapter is followed by a series of questions, some of which are problems, a list of suggestions for further reading (books, articles, etc.), and a list of suggested experiments, often fairly detailed. About 50 problems are offered and the answers are found in an appendix. 124 tables of useful and illustrative data are included. The style is excellent and the explanations clear. The mathematics of the book is not too elementary nor too difficult for the average college student. Binding, printing, and general appearance are very good.

In conclusion, the author is to be congratulated on a really excellent piece of work. There is reasonable doubt concerning its utility as a text for many courses, but none whatsoever concerning its value as a reference. Any teacher of the subject will find an abundance of stimulating ideas, in the way of presentation if not information. Every chemical library should possess a copy.

MALCOLM M. HARING

UNIVERSITY OF MARYLAND
COLLEGE PARK, MD.

INORGANIC AND THEORETICAL CHEMISTRY. *F. Sherwood Taylor*, Ph.D., M.A., B.Sc., Assistant Lecturer, Queen Mary College, University of London. Third edition. William Heinemann Ltd., 99 Great Russell Street, London, 1935. Chemical Publishing Co. of N. Y., Inc., 175 Fifth Avenue, New York City, exclusive agents in North and South America. xiii + 832 pp. 200 figs. 13.5 × 21.5 cm. $6.00.

In the preface the author states: "The book contains two concurrent courses. The matter in larger type is that which an intelligent student might be expected to study in his first year or eighteen months after matriculation; the matter in smaller type is supplementary—and is required by the University Scholarship candidate and second-year University student."

The first 200 pages of the book present the historical background and physical chemical fundamentals of general chemistry. Considerable space is given to atomic structure theory. The dotted formulas of Lewis and Sidgwick are used freely. The words neutron, deuterium, and positive electron are included and discussed. Considered as a whole and with respect to the limitation of the allotted space the theoretical material is well selected, well presented, and reasonably modern. On the other hand, on p. 188, an acid is defined as, "a compound containing hydrogen, which may be partly or wholly replaced by a metal, when a solution of the compound is treated with certain metallic oxides or hydroxides, such as those of the alkali metals: a salt and water being the only products." The name Brönsted does not appear in the index and only once in a footnote.

On page 131 the large print states that strong electrolytes are incompletely ionized in water solutions, while the subjoined fine print weasels as to the possibility of complete ionization of strong electrolytes. The idea of activity and activity coefficients does not appear.

On p. 137 the formula AgCl is used to represent dissolved silver chloride. Molecular equations are used to represent ionic reactions throughout the book.

The later 600 pages of the book contain chiefly descriptive matter. The preparation and properties of the elements and their compounds, in both the laboratory and factory, are described at length. Relatively little fine print is found in these pages. Many of the technical processes described have only local or historical interest. For example, it is rather surprising to learn, p. 682, that, "the action of manganese dioxide on hydrochloric acid is still used, though to a decreasing extent, to manufacture chlorine."

Though the title carries the name "Inorganic Chemistry" there is no mention of reactions in non-aqueous solvents, boron hydrides receive one paragraph, while the per acids, metal ammines, non-metallic halides, and oxyhalides receive only scattered mention. The same may be said of hydrides and substances of the intermetallic compound type. There is little or no attempt to present any generalized organization or theory regarding these and other significant classes of inorganic chemical compounds. The title "Elementary Theoretical and Descriptive General Chemistry" would have been more accurate.

Aside from the fact that the volume weighs nearly three pounds, it is mechanically acceptable, well bound, well printed, and reasonably free from typographical faults. As a classroom text the book will please the teacher who likes a full and extensive treatment. Under American conditions the book will find use as a supplementary text and as a one-volume reference book for teachers and students having limited library facilities.

JACOB CORNOG

UNIVERSITY OF IOWA
IOWA CITY, IOWA

INTRODUCTION TO THE MICROTECHNIQUE OF INORGANIC QUALITATIVE ANALYSIS. *A. A. Benedetti-Pichler*, Dr. Techn. Sc., Assistant Professor of Chemistry, and *W. F. Spikes*, M.S., Washington Square College, New York University. Microchemical Service, 30 Van Zandt Ave., Douglaston, N. Y., 1935. viii + 182 pp. 15 × 23 cm. $3.00.

This manual of microscopy applied to qualitative analysis is divided into three parts. In Part I, 18 pages are devoted to a description of and the use and care of the microscope. Part II, comprising 100 pages, gives instructions for carrying out about 60 experiments, 40 of which are the identification tests for the cations and some of the anions. Here the procedures are excellently described, the limits of identification stated, and circular blank spaces provided for sketching the forms observed. A systematic microchemical scheme for the separation and identification of the commoner cations is given in Part III (40 pages). The text is illustrated with about 60 drawings and contains a number of useful tables. The schemes of separations are shown diagrammatically and include limiting proportions.

The text is built on the course of instruction in microscopy offered at New York University. The most valuable feature of the text is the carefully worked out scheme of separation and in this respect is a most welcome improvement over previous texts in this field. It is doubtful whether in a one-semester course all the work outlined in the manual can be accomplished by the average student, and it might have been better for the authors to have designated in some way certain experiments, indicating the others as optional. The technics are described clearly, concisely, and with meticulous care, and the authors are to be commended for their accomplishment. Particularly helpful are the discussions on pp. 53–54, clarifying the rather confused ideas of "sensitivity," and on pp. 67–70 the relation between technic and quantity of sample.

Typographically, the work is neatly done and seems to be free from errors; on the whole, it makes a pleasing appearance. The large black squares inserted at points in the scheme of analysis where the procedures can be interrupted, detract from the appearance of the page; a less glaring device could have been used, but the idea of cautioning the worker is nevertheless a good one.

This text will doubtless prove very popular with those who have occasion to use the microscope in qualitative analysis.

CARL J. ENGELDER

UNIVERSITY OF PITTSBURGH
PITTSBURGH, PENNA.

P. Blakiston's Son & Co. Inc.

KIRK--College Chemistry

This book is a presentation of the fundamental ideas of general chemistry which starts as simply as does a high school text, reviews rapidly the basic facts and theories upon which the classical system of chemistry rests and progresses gradually and logically to the application of modern chemical ideas, to the classification and study of the usual chemical elements.

By Raymond E. Kirk, M.Sc., Ph.D., Professor of Inorganic Chemistry and Head of Chemistry Department, Polytechnic Institute of Brooklyn.

Ready Spring 1936.

HEIL--The Physical World

This book meets the need for a "cultural" physics. It is adapted for students not going into science. It combines astronomy, physics, and chemistry.

By Louis M. Heil, Ph.D., Associate Professor of Electrical Engineering, Ohio University.
426 Illus. 566 Pages. Cloth, $2.75

LANG--German English Medical Dictionary 4th Edition

A modern, pronouncing dictionary with related terms, chemistry, biology, botany, etc.

By Prof. Dr. Hugo Lang (Munich), Edited and Revised By M. K. Meyers, M.D. (Philadelphia)
Fabrikoid, $10.00

HACKH--Structure Symbols of Organic Chemistry

It gives students a definite image of atomic arrangement.

By Professor I. W. D. Hackh (San Francisco)
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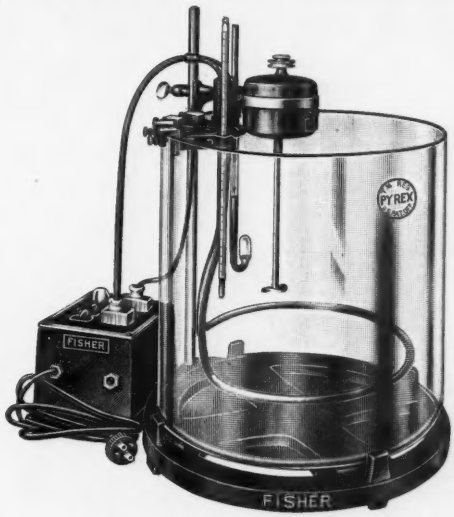

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TRADE ANNOUNCEMENTS

The Film-pressure Method

The complete title of Bulletin No. 102, recently issued by the *Central Scientific Company*, is "The film-pressure method for hydrophil measurements and thes tudy of monomolecular films with the Cenco hydrophil balance." Mimeographed, in loose-leaf paper binder, 17 pp., 21.5 × 27.5 cm. Pages 1–11 are devoted to theoretical discussion of the method, abstracted from a portion of a paper by Irving Langmuir [*Gen. Elec. Rev.*, **38**, 402–14 (1935)]. The remainder of the booklet suggests applications of the method, describes briefly the Cenco hydrophil balance and its use, and outlines the computation of results. Bibliography.

Gaertner Catalog

The *Gaertner Scientific Corp.*, Chicago, has recently issued Catalog L-2, "Optical instruments." 80 pp., 19 × 27 cm., index.

Kimble Catalog

An illustrated price list of Normax precision grade Kimble graduated glassware, issued by the *Kimble Glass Co.*, Vineland, N. J. 16 pp., 21.5 × 28 cm.

Combustion Tubes

"Pyrex" brand micro combustion tubes are made from "Pyrex" brand glass No. 172 which has been specially developed for use in higher temperatures. This new glass has a linear coefficient of expansion of 0.0000039 between 19–350 degrees Centigrade. The softening point is 930 degrees Centigrade, this being the temperature at which a glass rod 1 mm. in diameter suspended vertically elongates of its own weight at rate of 1 mm. per minute. Combustion tubing from this glass is satisfactory for temperatures as high as 850 degrees Centigrade for short periods, and for temperatures as high as 700 degrees Centigrade for continued use. *Corning Glass Works*, Corning, N. Y.

L. & N. Broadside

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A copy may be had by asking *Leeds & Northrup Company*, 4934 Stenton Avenue, Philadelphia, Pa., for "Broadside E."

One in a Hundred Million

Even as low as one part of mercury vapor in a hundred million parts of air by volume can be detected and registered by a device which has been announced by the *General Electric Company*. Mercury in appreciable quantities is used in numerous industries, and it is important that mercury vapor in the air be kept at a minimum.

In the new device the mercury vapor is detected by means of selenium sulfide, a light yellowish chemical compound which is turned brown by exposure to the vapor. Knowing how long the selenium-treated paper has been exposed, and determining the intensity of the brown by comparison with a chart, the concentration of the mercury vapor can be determined quickly.

The color scale provided with the equipment has six colors uniformly graduated from the lightest color distinctly visible, to the darkest color which is produced when all the selenium sulfide is consumed. The chemically treated paper is supplied in strips seven-eighths inch wide and 62 inches long, wound on spools and in air- and light-tight containers.

Blister-proof Micarta

A new heat-resistant material suitable for application on bar, counter, and table tops or any other surface likely to come in contact with lighted cigarettes and cigars has been developed by the *Westinghouse Electric & Manufacturing Company*. Known as Blister-Proof Micarta, it is made by molding a thin metal sheet directly beneath the surface of the Micarta plate. This sheet acts as a rapid conductor of heat, preventing high temperatures in local spots which otherwise might cause blistering of the material.

New DuPrene Plant

The Rubber Chemicals Division of the *du Pont Company* announces that the new plant for the manufacture of its synthetic rubber, known as DuPrene, which has been under construction for the past year, is now completed and is producing at the rate of approximately one million pounds a year. The plant is located at Deep Water, New Jersey, opposite Wilmington, Delaware, where all shipping facilities are available both by rail and water. The building of the new plant was made necessary by the greatly increased demand for this synthetic rubber. Since the announcement of DuPrene in 1931 a great amount of technical work has been done in many industries in applying this synthetic product to their needs. Since DuPrene compositions will withstand higher temperatures than those of natural rubber and are more resistant to oils and chemicals and have less tendency to crack when repeatedly stretched and flexed, they soon found wide utilization.

Handling Acid with Safety

Ten-gallon carboys of hydrochloric, nitric, and sulfuric acid have always been dangerous to handle. In the *Westinghouse Lamp Company*, Bloomfield, New Jersey, only one serious injury has resulted from acid burns, but the potential danger is always great enough to warrant rigid safety measures. A new method of ejecting small quantities of acid from carboys has been adopted and is expected to minimize the risk in this work.

Acid was formerly ejected by applying air pressure of a few pounds to the carboy, forcing a flow of acid into filter flasks. The likelihood of breaking the carboy seemed remote indeed, but one carboy eventually did break with serious consequences to the worker. Further danger was also involved when tilting a full carboy to empty it into an acid vat at one operation. Splashing acid always presents a hazard.

Now a simple suction device is employed to draw small quantities of acid from a carboy for use in processing lamp filaments. A filter flask is plugged with a rubber cork and two glass tubes. One tube drops down into the carboy; the other is connected to a rubber suction hose. Air is withdrawn from the flask, creating a section which draws acid up from the carboy.

An interesting feature of this ejector device is the method of creating the suction. The rubber hose is attached to the suction side of a laboratory water filter. As air is released from the pressure line through the nozzle of the water filter, it creates a suction in the hose, which, though slight, is sufficient to create enough vacuum in the filter flask to draw acid from the carboy.

A different siphoning arrangement is employed to empty a full carboy into an acid vat at one operation.

The carboy bottle is plugged with a cork and two glass tubes, both of which extend to the bottom of the carboy and both of which fill with acid to the level inside. One tube is a siphon that runs out, over, and down into the vat below. The other tube parallels the first one and connects with it at the bottom of the bottle. Outside it is topped by a rubber bulb.

Pressing the rubber bulb forces acid up into the siphon tube until it spills over and starts a flow down into the vat below.